

**Rural Transportation Planning Analysis in Chang-Hwa County, Taiwan:
System Dynamics Perspective**

by

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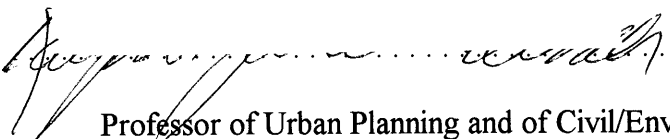
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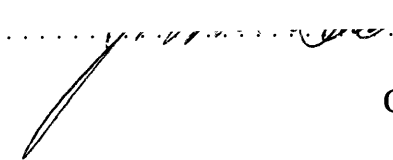
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ABSTRACT

Transportation is not merely a derived demand, but a determinant of new production possibilities. In developing economies, where the lack of mobility is self-evident, it is absolutely necessary to consider the catalytic impacts of transport services. Transportation not only directly affects the overall output in an economy through accessibility and costs, but also stimulates and influences the shift in the demographic sector in terms of population movements and unemployment rates. To successfully plan for the development of a region, one must understand the possible causal relationships, feedbacks and interactions between the different sectors of both the investment region and the possible spatially impacted region.

In this study, the impacts of three investment strategies for the Dro-Shu Coast region, in Chang-Hwa County, Taiwan, are evaluated through the use of a computer simulation and system dynamics methodology. The model consists of two regions -- the region in which investment is provided and the region that is spatially impacted due to this

investment. The hypothesized interrelationships of the main sectors (demographic, economic, and transport) and components of each region were first developed as causal submodels. Secondly, the submodels were synthesized to form a comprehensive system dynamics computer model represented by approximately 280 equations to evaluate the three strategies: (1) Do Nothing, (2) Investment in Roads Only, and (3) Investment in Roads, Drainage and Irrigation.

Sensitivity analyses were performed on the key socio-economic variables (Drainage, Irrigation, Fertilizer, Mechanization, and Regional Migration) to determine which variables most significantly influence regional behavior. These tests showed that an implicit assumption of the availability of drainage irrigation, mechanization, fertilizer and trucking fleet can seriously overstate the impacts of investments in roads if these key resources are limited or not available.

The investment strategy in Roads, Drainage and Irrigation provided the greatest net benefits and most favorable socio-economic characteristics in terms of population level, regional income per capita, out-migration, and unemployment. So, given its financial feasibility, it is recommended for implementation. Further, it is also suggested, because of the model's demonstrable flexibility, that it be used for post investment analyses and future model calibration.

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Chapter 1

Introduction

1.1 The Role of Transportation in Economic Development

Essentially, transportation in terms of economic development is 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 total 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 then the eventual growth rate and specialization of a region). Transportation is therefore not only a derived demand, but a determinant of new production possibilities. Transportation also has important non-economic roles, such as political, social, and military cohesion of a state. Therefore, transportation is often regarded as the most important sector for economic development (Hofmeier, 1972, p.1-10).

In developing countries, this concept of transportation as a determinant of new production possibilities and demographic change has long been recognized by those concerned with the planning of economic growth. In 1960, economist Walt Rostow (1960, p.55), in his text Stages of Economic Growth once stated:

“...the preparation of a viable basis for a modern industrial structure requires that quite revolutionary changes be brought about in two non-industrial sectors: agriculture and social overhead capital, most notably in transport.”

Also, in 1962, E. K. Hawkins (1962, p.62) echoed similar statements in his text Road and Road Transport in an Underdeveloped Country:

“...the one same generalization that can be made about the underdeveloped countries is that investment in transport and communications is a vital factor.”

The search over the past thirty years has been for “appropriate” methodologies to evaluate the catalytic impacts of transportation investment in already identified-resource-endowed regions, in order to prioritize the allocation of limited funds, skills and equipment in less developed regions (LDRs) of developing countries.

1.2 Background and Problems of Developing Countries

Agriculture and agricultural-related industries dominate the economy of most LDRs of developing countries. The rate of development in LDRs of developing countries, therefore, depends on the success of their agricultural programs. First, because agriculture provides the largest amount of employment; second, unless production and productivity in agriculture are increased to the point of meaningful surplus over national consumption needs, then the resources (such as labor, funds) necessary to make a push in the industrial sector would be lacking.

Each year at least 20% or as much as 40% of the developing countries budgets are spent on transportation or transportation-related projects, with the sincere belief that transportation is an obvious prerequisite for increased production and national integration. Yet it is not uncommon to observe large uninhabited, or at most sparsely populated, poorly accessible regions, and smaller zones, especially cities and/or towns with severe

overcrowding. Also, even within a mere hundred miles of travel, more than one mode of transportation are required to complete a trip. Veritable land masses are served as if they are islands because of the pattern of transportation development.

The above evidence points to the significant degree of uncoordinated national strategies for development. On the one hand, we have the national economic planners who are only concerned with the global or sectoral effects of their decisions and ignore their spatial consequences. On the other hand, we have the national physical planners, often located in the ministries of public works or construction; they are heavily "design" oriented and, at times, appear more concerned with the minimization of their budget than with the overall impact of their design. National economic planners must be made more aware that most their decisions are not spatially neutral, and physical planners must acknowledge the limits placed on their plans by the state of the national economy, if national spatial policies are to improve the national environment (Tang, 1989, p.20).

In most LDRs, the net effects of the current policies and practices of government is never considered, and this generally accentuates the tendency towards concentration. In addition, discrimination against the rural sector makes everything worse (Chiang, 1988, p.25).

The premise of transportation planning has been that travel demand is repetitive and predictable and that the transport system should be designed to meet this future demand. Thus, the "predicted highest users benefits" per route decided where roads of shipping, or other modes are provided. This strategy has resulted in an over-emphasis on high volume facilities and to the detriment, not only to accessibility per se of the rural

regions, but also to the rate of which technological “know how” is transferred to these regions. Not surprising, the resultant benefits of the high volume facilities were disappointing (Edwards, 1978, p.1-20), since the concept of traffic volume (users benefits) used for the evaluation was more relevant to the industrialized countries that developed these methodologies. The value of passenger travel time saved and vehicle depreciation are questionable determinants of real benefits in countries with high unemployment rates and low vehicles per capita.

1.3 The Needs of LDRs in Developing Countries

Because a road, a rail or shipping route is built to stimulate economic growth, the appropriate basis of measuring benefits would seem to be the increases in production, employment and services instead of traffic flows per day. However, once this approach is taken, accompanying investments must also be considered since a road or other transport facility by itself is not sufficient to increase production. Thus, the value of the output and input which may be attributed to the road alone may be no longer be of any main interest. Of 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, traffic (existing, attracted, and generated) is a poor substitute for determining feasibility, and the main reason for estimating traffic volume is to determine what type of facility should be constructed (Chiang, 1992, p.24). Furthermore, the impact of the integrated set of investment implies a data base involving disciplines other than transportation.

Specifically, these direct and induced impacts of transportation and related investments on the state's production and shifts in population need to be evaluated. A comprehensive and coordinated planning approach may specifically indicate the above needs.

1.4 Objectives

There are definite linkages and feedback between the transport sector and the other main socio-economic sectors in any regions, and this feedback is even more pronounced, it is contended (Hofmeier, 1972, p.10), in poorly accessible agri-based regions. The question then arises, what level of transportation is required, within the given budgetary and other constraints, to positively influence output and effectively reduce undesired urban in-migration?

It is the intent of this research to explicitly incorporate the transportation activity (variable) in a comprehensive system model; and study the impacts of various investment strategies in transportation and related inputs on the economy as a whole through the methodology of system dynamics and the techniques of computer simulation.

Specifically, the objectives are:

1. To develop computer simulation submodels, using the methodology of system dynamics, for the main sectors of an agriculturally based economy.
2. To link the submodels to form a single comprehensive model, thereby accounting for the inter-relationships and interactions of the different sectors of the economy.

3. To apply the model to Taiwan's Chang-Hwa County, an agriculturally based, less developed region, as a tool for strategic transportation planning to determine the impacts of transportation and related investments on the economy as a whole.
4. To use the model to determine the appropriate data base for transportation planning in LDRs of developing countries.

1.5 Scope and Organization

Conceptually, an agri-based economy depends on mobility and accessibility. If the desired level of transport is not provided, the economy is likely to stagnate at a subsistence level and produce possible unwanted urban in-migration. Furthermore, decision makers in LDRs invariably have to choose among several projects because of their lack of funds and necessary skills to satisfy the numerous demands of the state. Because a significant portion of their funds comes from central government, they must produce feasibility studies to justify the requested funds. Even these parts, the nature of transportation (i.e., high initial cost and not easily transferable) demands astute allocation of funds if the growth of the other sectors, for example, health, education, etc., are not to be compromised. Thus, any proposed methodology for the evaluation process should provide explicitly, the answers to questions of : rate of return and prioritization of investments, impacts on production, employment, income and migration, among others, for various policies.

The conceptual model will first be developed, then the model will be calibrated with data from Chang-Hwa County, and finally used to evaluate the socio-economic impacts of the following policies for the county: (1) the continuation of the status quo, i.e., maintenance of the current facilities and "sporadic" infusion of small sums of

developmental funds in the scenario (which is the case in most developing countries); (2) investment in transportation; (3) investment in transportation and drainage and irrigation (integrated package); and (4) extensive sensitivity analyses to determine which of the variables drives the model in order to identify a more appropriate data base for future model building and planning.

The thesis consists of seven chapters. In chapter 2 the current state of the art for planning of transportation is discussed, and a brief overview of the basics of system dynamics are also provided. The intent of this chapter is to place system dynamics in perspective to the current state of art, thereby identifying the need for this approach. The conceptual submodels and comprehensive model, with their intra- and inter-sectoral linkages and feedbacks are developed and explained in Chapter 3. Chapter 4 is devoted to model calibration and application to the Chang-Haw County scenario under various investment strategies. In Chapter 5 the results of the outputs from Chapter 4 are analyzed to determine the policy and region with the most desirable socio-economic impacts on the county. In Chapter 6 extensive sensitivity analyses are undertaken on the main hypotheses used for the developed model. Chapter 7 is a summary of the thesis, an indication of its usefulness and possible future research efforts that should be undertaken for the analysis of investments in the economic infrastructure of potentially viable agricultural regions of developing countries.

Chapter 2

A Review of Principal Planning Approaches

Model building is a rational attempt to forecast the future behavior of a system. Past transportation planning models based on the analyses and solutions of the demand component of the transportation system have not been able to deal with some significant long-term induced problems such as pollution, congestion, urban blight, etc., in the developed countries. Furthermore, the application of basically similar techniques for transportation planning in developing countries has led to the funding of high volume roads and to the apparent neglect of low volume transportation facilities and their developmental impacts on the other sectors of the economy.

Recently, the limitations of component analyses have been realized, and within the past thirty years, several comprehensive models have been developed to account for the total system impacts. These models were developed based on linear programming technique, input-output technique, or system dynamics technique. These three approaches will be briefly reviewed in this chapter according to the following outline. Sections 2.1 to 2.3 are devoted to a critical review of the present state of the art in planning (i.e., the main models in terms of their structures, variables, and applications). Section 2.4 places the proposed system dynamics approach in perspective.

2.1 The Traditional Approaches

There are basically two main approaches for estimating benefits of road and related investments in rural regions: (1) road user's saving, and (2) producer's surplus.

Road user's savings approach focuses on traffic volume and cost of transport and is best suited for high volume roads. The methodology follows the traditional 4-step procedure used in urban transportation planning, that is (1) trip generation, (2) trip distribution, (3) modal split, and (4) network assignment. Benefits are estimated in terms of the difference in operating costs between that of the traffic on the new road and that of alternative road, or on the same road before improvements. In areas of low traffic volume and low economic activities, the user's saving based on traffic volume is poor indicator of the impact of the investment. Empirical evidence has shown that indirect benefits are significantly larger than direct users benefits (Gwilliam, 1976, and Chen, 1993). Furthermore, the quantification of operating costs on dirt roads and/or poor maintained roads is difficult and can seriously influence the decision.

Producer's surplus method quantifies the developmental impact of transport cost savings and complementary investments within the area of influence of a road. The net income (producer's surplus) of farmers and transporters prior to the proposed investment is determined from an analysis of baseline data on crop land area and yields, production costs, ex-farm prices, marketed input and local consumption, together with transport costs and prices. Changes in these data are then forecasted if the proposed investment is made and subtracted from those changes that would have occurred without the investment. By these means, a benefit can be accumulated year by year and compared with the cost of the project. A calculation is then made of the rate of return of the package of investments I transport combined with other complementary investments (Tingle, 1980, and Chen 1986).

Both user's savings and producer's surplus approaches assume that production will express itself directly through the transport price mechanism. The complex set of interrelationships, which exist among production and transport factors, is not brought out by either method. The approaches are unidirectional -- results of one step (phase) of the model are fed into the next step -- and neither casualties nor feedbacks among sectors of the rural economy are addressed by these techniques. Moreover, investments (and their impacts) are treated as if they are spatially neutral in the sense that only the region where the investments are made is affected. Empirical evidence, however, has attested to two trends from transport (especially road) investments in low economic activity regions: (1) transport has significant noneconomic impacts -- for example, inter-regional migration and accelerated transfer of "know-how" among others, and (2) transport is but only one component (a necessary one) for the development of a region. That is, transport equals development is a misconception (Trngle, 1980, and Edwards, 1978). Thus, in the traditional approaches, benefits are measured too specifically and attributed too narrowly. These findings have resulted in researches calling for a more comprehensive approach to the evaluation of transport investment. Odier (1963), in his discussion of benefits, states that road construction affects the nation as a whole and ..."efforts must be made to access them as a whole, which results in the first place in the concept of the effects on national income, and in the second place in the customary classification into direct and indirect effects."

The system dynamics methodology proposed in this research has the capabilities to incorporate explicitly intra- and inter-sectoral relationships and feedback phenomenon.

However, before an outline of the system dynamics methodology is presented, the pros and cons of two other approaches --(1) Linear Programming, and (2) Input-Output -- that have gone beyond the traditional methods are presented.

2.2 Linear Programming (LP) Technique

In the LP approach, the transport variables are explicitly incorporated in the models. The models measure the benefits from resource savings, increase in output, or changes in cropping patterns which result from an improvement in the transport system under varying price and technology assumptions given local or regional resource constraints. The regional economic activity, without transport investment, is expressed as a constrained maximization problem, and then with investment in transportation. The programming solutions of the two problems are then compared to show the impact of the investments (Rao, 1991).

Typically, a LP problem for a developing region may be formulated as follows (Buduh and Hobeika, 1980):

$$\text{Maximize } Z = C_i X_i + C_t Y_t \quad (1)$$

Subject to:

$$A X_i + D Y_t \leq B_i \quad (2)$$

$$F X_i - G Y_t = 0 \quad (3)$$

$$X_i, Y_t \geq 0 \quad (4)$$

where

C_i : net contribution to the economy of one unit of the main activities of the region;

X_i : a unit of the main activities of the region ($i = 1, 2, \dots, n$ and $n =$ number of activities except transportation);

C_t : net contribution of one unit of the transport activity;

- Y_t : a unit of transport activity for the mode under consideration;
- A : input coefficients in terms of time, person hours, and materials, etc., or the amount of resources consumed, by unit measure of each activity in the region;
- D : input coefficients of resources consumed by one unit of the transport activity under consideration
- F : demand coefficient for transportation by the economic activities of the region (ton-miles)
- G : supply coefficient for transportation by the economic activities of the region (ton-miles)

Equation 1 is the objective function that the model optimizes. Transportation, like any other activity, contributes to the region's output, and so it is included in the objective at a positive level. Equation 2 is the constraint equation that guarantees that no more than the available resources can be consumed. Equation 3 is the equilibrium equation; i.e., the demand for transportation by all the activities must be balanced by the supply of transportation. An optimal solution occurs when the demand for transportation equals the supply; i.e., the quality and level of transportation influence the total net benefits of the region. Equation 4 guarantees no negative outputs by any of the activities.

The method is best suited for regions where minimum infrastructure and some form of economic activities are already in place, and transportation is perceived to be the main constraint to accelerated economic growth.

2.3 The Input-Output Method

Input-Output Analysis, originally developed by Leontief (1966), is a name given to a modeling procedure in which the output of each industrial sector is set equal to the input

consumption of that product by other industries and consumers. The models can be interpreted in terms of the block diagram and matrix algebra techniques so familiar to system engineers.

The concept of input-output analysis can be illustrated in the following example. Suppose there are four industries with output rates X_1 , X_2 , X_3 , and X_4 units of value per unit of time. The output of each industry is used by itself, by the other three industries and by the consumers. The interindustries transaction can be shown in a tabular form in Table 2.1.

	Purchasing Sectors					Demand Sector	
Producing Sectors	Intermediate Demand					Final Demand	Total Demand
	X_1	X_2	X_3	X_4	Total		
X_1							
X_2							
X_3							
X_4							
Total Inter Industry Demand	----- $\sum_{i=1}^4 a_{ij}X_j$ -----						
Primary Inputs (Value Added)	----- P_i -----						
Total Production	----- $\sum_{i=1}^4 a_{ij}X_j + P_i$ -----						

Table 2.1 Interindustry Transaction Matrix

In matrix form, the output of each sector can be expressed as:

$$X_i = \sum_{j=1}^4 a_{ij} X_j + Y_i$$

where:

X_i : value of the output of the i th industry;

a_{ij} : technological coefficient where i refers to the column and j to the rows;

Y_i : the value of the final demand for the output of the i th industry (sector);

P_i : the value of the primary factors (e.g., land, labor, etc.) used by the i th industry; and

$a_{ij}X_j$: the value of j output that is sold to the i th industry

The basic idea behind the input-output analysis is that a system is forced or driven by a set of final demand Y_i . It is assumed that the demand Y_i can be satisfied, and the total output X_i 's which satisfy these final demands can be found. The overall result of these transactions may be thought of as "pressures" on the economy. Where the economy is slack, the "pressure" should be a positive factor in stimulating production; and where it is not slack, the "pressure" could create problems by placing demands on factors which are already in short supply (Roberts, 1978).

The method (model) provides information explicitly on both implied output and induced output. Implied output defined as (in the case of agricultural sector) values of farm output from the project, purchased input used in farm production, trade and transportation output from involved in delivering the farm output to the market, and the output from those industries which purchase the farm output. Induced output covers the interindustry, or intermediate requirements of those industries which apply the farming

activity and purchase its output. As such, the model indicates the use and the generation of resources of special importance to economic growth and also the regions where externalities might occur. In this regard, an analysis of the total output and input will identify the "pressure" points and/or needs of the region to satisfy the projected final demand, and as such does provide a degree of comprehensives.

The model suffers from some of the similar limitations of the LP technique such as linearity that requires a constant return to scale, and this may not be a correct assumption for the region. Secondly, most less developed region of developing country may not be able to afford the extensive and intensive studies required to develop the technological coefficients of the input-output table.

Other limitations of the input-output concept are the difficulties in applying it to a typical transport development project in which a small region is studied. Also, the prediction of the final demands for each sector would be extremely difficult in less developed regions with a poor data base. Moreover, although causality is addressed by the model, neither spatial impacts nor the feedback phenomena nor constraints are explicitly incorporated.

The technique may be best suited to regional scenarios that already possess a significant data base and are already using this technique in their planning hierarchy as a guide for transport demands.

2.4 System Dynamics in Perspective

The traditional approach is by and large founded primarily on simplifying statistical relationships between the different variables (activities) that define the behavior of the

regional economy. These simplified relationships are projected into the future without any serious attempt to quantify time lags (in the case of construction), feedbacks and non-linearity behavior through transient stage and spatial impacts that are invariably evidenced after project implementation. Researchers (Wang and He, 1988) are convinced that transport investments have national impacts and it is equally important that transport is but only one of the many factors which determine economic growth of a nation. Furthermore, the complex interactions and inter-relationships of transport and of the other sectors of the economy need to be understood so that investments in transportation can be more wisely and beneficially used.

Moreover, in scenarios used with an insufficiency of financial and technical resources and a significant lack of coordination among the different agencies, it is important to provide a methodology that addresses explicitly the views of other agencies when it comes to allocating the funds that their agencies are seeking.

The system dynamics approach can specifically address the above needs, since it has the capability not only of using realistic statistical relationships (linear or nonlinear), but also to incorporate causality and feedback explicitly.

A system dynamics operating model can be used to communicate and incorporate the views and opinions of groups not involved in building the model. By experimenting with changes in policies and model parameters (sensitivity analyses) and observing the effects of these changes on behavior, these groups can help or be helped to better understand the dynamic forces at work in the real world system.

Ever since the development of system dynamics by Professor Forrester in 1968 (known then as Industrial Dynamics), the methodology has been increasingly applied to a wide range of socio-economic problem as documented in Roberts, Managerial Applications of System Dynamics (1978). However, very little use has been made of this methodology in the field of transportation planning for poorly accessible regions. In this research, the system dynamics capabilities for explicitly incorporating causality and feedback system principles will be utilized to evaluate both direct and spatial impacts of transport and related investments in a less developed region.

2.5 A Description of System Dynamics Methodology

System Dynamics, a field which extends from the work begun by professor J. W. Forrester at the MIT Sloan School of Management, is a methodology for analyzing the behavior of complex dynamic systems. Through simulation techniques, if the conditions are known at one point in time, some logic or policy expressed as equations can be used to compute the conditions at the next point in time. In this way, one can move step-by-step through time producing various patterns based on various technological alternatives, institutional policies, or economic strategies. Professor Forrester's methodology provides the foundation for expressing in mathematical equations the structure of the system upon which policy acts (Forrester, 1961 and Sage, 1977).

In undertaking system dynamics analysis of a problem, the steps involved are: (1) causal loop programming, (2) flow programming, and (3) the conversion of the flow diagrams into sets of simultaneous difference equations.

2.5.1 Causal Loop Programming

The first step is to hypothesize the underlying structure of the system that is causing and maintaining the problem. The causal loop diagrams show the existence of all major cause-and-effect links, indicate the direction of each linkage relationship between variables, and denote major feedback loops and their polarities.

In developing a causal loop diagram, each link is represented by an arrow and given a plus (+) or minus (-) directional sign, usually shown near the arrowhead, and is referred to as a positive or negative linkage. A linkage is a cause-and-effect relationship between two variables in which the variable at the tail of the arrow is the cause (independent variable), and the one at the head of the arrow is the effect (dependent variable). A positive linkage means that the independent and dependent variables vary in the same direction (both increasing or decreasing). A negative linkage, on the other hand, implies that the two variables it connects vary in opposite directions (one increasing and the other decreasing).

A feedback loop is formed when two or more linkages are connected in such a way that, beginning with one variable, one can follow the arrows and return to the starting variable. Like linkages, feedback loops are also identified according to their polarities, positive (+) or negative (-). In a positive feedback loop, the loop acts to reinforce variable changes in the same direction as the initial change, contributing to sustained growth or decline of the variables in the loop. In a negative feedback loop, the loop acts to resist or to counter variable changes, thereby pushing towards a direction opposite to change, contributing to fluctuation or to maintaining the equilibrium of the variables in the

loop. A simple method of determining loop polarity is to count the negative linkages in the loop. An odd number of negative links indicates a negative feedback loop. Zero or an even number of negative links indicates a positive feedback loop.

Figure 2.1 provides an illustration of the cause and effect and feedback phenomena described above. As described in this figure, one can conceptually think of investment fund and demands for roads influencing the rate of road construction, which in turn increases the miles of road network provided. An increase in network mileage (also represented by road density) should: (1) increase the accessibility of the region, and (2) reduce further demands for roads. Likewise, an increase in accessibility should positively influence land development rate, a main determinant of future area under cultivation. Figure 2.1 provides a succinct description of the above concept using the underlined words as the main variables explaining the behavior of the system.

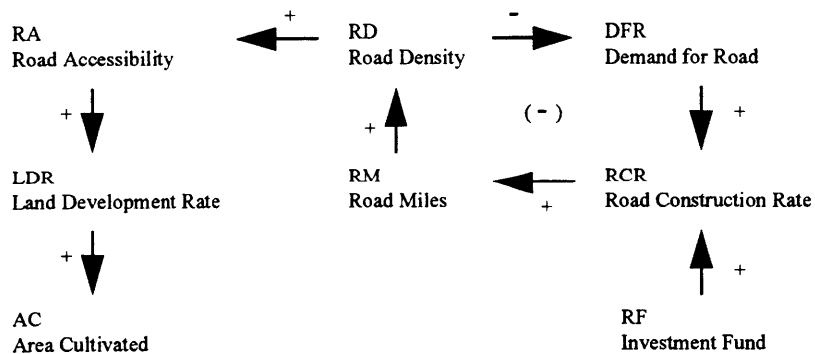


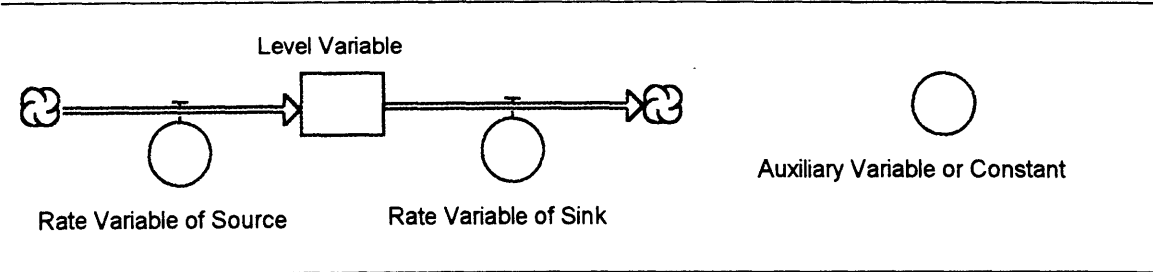
Figure 2.1 An Illustration of a Causal Diagram-Feedback Phenomenon of the Transport Demand/Supply Behavior

2.5.2 Flow Diagramming

From a system dynamics perspective, all systems can be represented in terms of variables. A variable is a quantity that changes as time evolves. A variable may be a

decision variable, or it may be a quantity that is affected by such a decision variable, or it may be a quantity that is affected by such a decision, or it may be a changeable input to a decision (Forrester, 1961). When a variable is not affected by other variables inside the system being analyzed, the variable is termed exogenous or outside of the system. A variable that is subject to effects of other variables in the system is termed endogenous. In system dynamics there are three types of basic variables: (1) level variable -- which is an accumulation, or integration, over time of flows or changes that come into or go out of the level; (2) rate variable -- a flow, decision, action or behavior that changes over time as a function of the influences acting upon it; and (3) auxiliary variable -- used for clarity or simplicity, which is a combination of information inputs and concepts. In Table 2.2, the flow diagram used in system dynamics are summarized. In visually representing a system dynamics model, causal loop diagrams (typical of Figure 2.1) are generally used for purposes of communication. However, for formal documentation of a model, formal flow diagrams are developed for equation writings. Figure 2.2 provides the formal flow diagramming for the causal diagram of Figure 2.1 from which the system dynamics equations can be developed.

Table 2.2 System Dynamics Flow Diagram Conventions



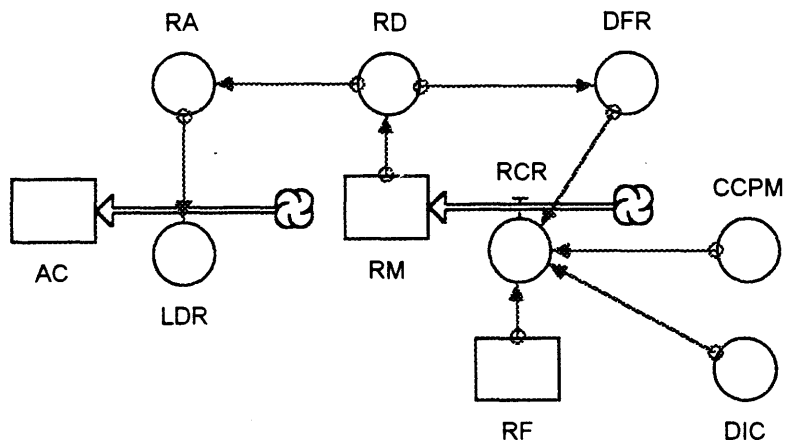


Figure 2.2 An Illustration of Flow Diagramming for Transport Demand/Supply Behavior and the use of System Dynamics Symbols

2.5.3 STELLA Equations

Equations permit expressing model relationships in explicit quantitative terms that can be simulated manually or by a computer.

The development of a formal set of equations for the level variable RM (Road Miles) and the rate variable RCR (Road Construction Rate) in Figure 2.2 are presented as follows:

L	$RM = RM + (DT) * (RCR)$	1.0
N	$RM = 100$	1.1
R	$RCR = \text{MIN}(DFR, (RF/CCPM)/DIC)$	2.0
C	$CCPM = 200000$	2.1
C	$DIC = 5$	2.2

where:

RM : Road Miles (miles)

RCR : Road Construction Rate (miles/year)

MIN : A Minimum Function

DFR : Demand for Road (miles)

CCPM : Construction Cost Per Mile (\$/mile)

DIC : Delay in Construction Time (years)

DT is the increment in time -- a predetermined time interval by which solutions are sought; Equation 1.0 provides the total number of miles in the road network at a given point in time; Equation 1.1 is the initial value of road miles at the beginning of the simulation; Equation 2.0 provides the rate at which road is constructed in the future for any given time increment (DT); Equation 2.1, a constant, is the assumed cost of construction per mile of road; and Equation 2.2 incorporates the delay envisaged between the starting and completion of construction. The simulation is executed by performing a sequential solution to all equations. The sequence is as follows:

1. Compute all values at present point in time based on all values given at previous point in time and the rates during this current time interval;
2. Compute the new rates over next time interval from the values of the levels at current point in time;
3. Compute output variables and place them in an output file;
4. Shift above steps ahead one increment DT for the next cycle of computation.

More detailed information on system dynamics and STELLA simulation language can be obtained from Forrester (1961) and High Performance Systems Inc. (1990).

Chapter 3

The Underlying Structure and Conceptual Causal Model

As evidenced by the literature search, it is quite clear that investment in transportation in poorly accessible regions results in significant regional and national impact which often are more important than the traditional road user's costs and benefits generally used for the evaluation of the investment. Furthermore, these impacts are the results of the complex interactions between the socio-economic factors that define the region's performance. Thus, it is necessary to identify the extensiveness and intensiveness of these impacts through the structural inter-relationships, the causal and feedback phenomena of and between the main regional socio-economic factors, if a meaningful development plan of the region is to be provided. Further, it is contended that System Dynamics methodology can specifically address the above needs since it is capable of explicitly incorporating and validating the hypothesized behavior, and through the technique of computer simulation, tracing the hypothesized behavior through transient state to steady or equilibrium state. In this chapter the fundamental characteristics of system dynamics methodology and the conceptual model will be illustrated.

In Section 3.1 the main underlying features -- (1) hypotheses or assumptions and mathematical formulation, (2) simulation, (3) transient state, and (4) equilibrium state -- referred to earlier are discussed. Section 3.2 outlines the phases of the proposed methodology. In Section 3.3 the domain feedback loops of the main sector of the

economy and a generalized conceptual model to be used for the evaluation of transport and related investments are developed.

3.1 The Underlying Concepts of System Dynamics

Since it is very often too costly and impractical to experiment with the real world problems, one resorts to modeling. Model building inevitably involves assumptions about the real world behavior, and therefore results in limitations in the utilization of the model's output. Since system dynamics is a modeling approach, the above problems are also true for its output. The question that obviously arises is: how significant are these limitations for the outputs of the proposed system dynamics methodology? This question is best addressed by an examination of the main concepts that constitute system dynamics methodology. These concepts are:

- 1) Hypotheses and mathematical formulation of the behavior;
- 2) The use of aggregation; and
- 3) Simulation.

A brief review of these concepts is necessary as a prelude to the model development process, since the confidence with which the model's output is regarded depended strongly on the concepts used.

3.1.1 Hypotheses in System Dynamics Methodology

It is clear that the number of variables or facts of all but the simplest (and probably trivial) problem associated with economic growth is so large that the selection of the facts to be studied must be considered. But on what basis would the observer from the infinite

complexity of reality a manageable subset of facts or variables to study? It seems that selection would be depend on some hypotheses of the causes and consequences of economic growth (Jones, 1975).

Usually we approach the problems only at the level of symptoms forearmed with a mathematical model that the problems or symptoms must fit. This lack of understanding of the structure of the underlying system often leads to wrong conclusions regarding the problem (Sage, 1977). The use of hypotheses or assumptions in system dynamics approach affords us a useful way to deal with problems involving many considerations, interrelationships and feedback phenomena. Assumptions of the relationships of the forces or facts that have created and continue to sustain the problem are made. Relevant data are then gathered and compared to the hypothesized behavior. This process is continued in an iterative manner until the behavior is acceptably replicated. Thus, through the use of hypotheses, a “more realistic” model is developed in system dynamics methodology.

3.1.2 Aggregation in System Dynamics Methodology

In the development of any model of socio-economic growth, some degree of aggregation is necessary. What is important is that care should be taken not to make the simplification in such a manner that the model falls to pieces when the variables are disaggregated or removed.

The purpose of the developed model is to provide comprehensive (social factor included) analyses of proposed investment policies. Comprehensives suggest breadth (i.e., macro approach), and economic quantification suggests depth (i.e., detailed or disaggregated treatment). Budgetary limitations demand a compromise; however, the

compromise provided by aggregation must be representative (i.e., not oversimplified), if the model is to be useful. System dynamics methodology provides for checks for representativeness through the technique of sensitivity analyses on the main aggregated variables. Where such disaggregation is warranted (as indicated by sensitivity analyses) and the cost of modeling is affordable, such disaggregative inputs would strengthen rather than destroy the output of the model.

For example, the labor force may be aggregated in the model as a fraction of the entire population. This assumption implies that in the case of a growing economy, the labor force grows at a constant exogenous rate, and no element of the model under consideration can affect the overall labor force growth. Since real growing economies are often constrained by particular kinds of skilled labor, the constant exogenous growth rate of labor might be considered as a drastic oversimplification. However, if it is conceived that a particular skill, or for that matter, age group is constraining growth, then the disaggregation can be incorporated without any apparent modeling problem. Thus, cost and/or time rather than modeling capabilities are the true constraints in system dynamics.

3.1.3 Simulation in System Dynamics

In any economy, there are forces that drive the economy, and it is necessary to identify whether these forces and feedback phenomena tend towards steady state behavior or continue to induce growth or decline (i.e., transient state behavior). This process is often referred to as the stability problem of the region.

The concepts of both equilibrium and transient states are important characteristics in growth models of economic development. Equilibrium state is used as a benchmark for

the study of the system; in general, it is taken as that configuration of the economy from which there is no tendency to change. Thus, the factors that constraint further growth can be identified and possibly perturbed (through policy changes) to induce growth. Transient state provides information on the trace of the behavior of the system through time, thereby providing for more accurate economic evaluation of receipts and disbursement of the impacts of a given policy. Furthermore, an economy in transient state may be more easily manipulated if explicit knowledge of the factors that induce the changes is provided.

System dynamics methodology, unlike the main models reviewed in Chapter 2, makes use of the tool of simulation, thereby explicitly providing a trace through time of the impacts of a given investment strategy. Furthermore, through sensitivity analyses and trace of the behavior, the variables or forces that drive the economy may be better understood to follow for timely modification.

The review of the underlying structure of the proposed methodology --system dynamics -- shows that even though the model is based on hypotheses and aggregation, the outputs can be utilized with confidence.

The model development process is dynamic because of the iterative process of mathematical formulation and calibration to the desired replication of the perceived behavior. It is also flexible enough to allow for disaggregation, where such disaggregative efforts will lead to improved reliability of the outputs, without destroying the overall structure and usefulness of the developed model.

3.2 Outline of Method of Approach

Figure 3.1 shows a flow diagram of the twelve steps involved for the provision of the model, analyses, and recommendation for the development of a potentially viable rural region. Only a brief outline of each step is offered at this stage as a quick synopsis of the research. The detailed development of each step or phase is the purpose of Chapter 4.

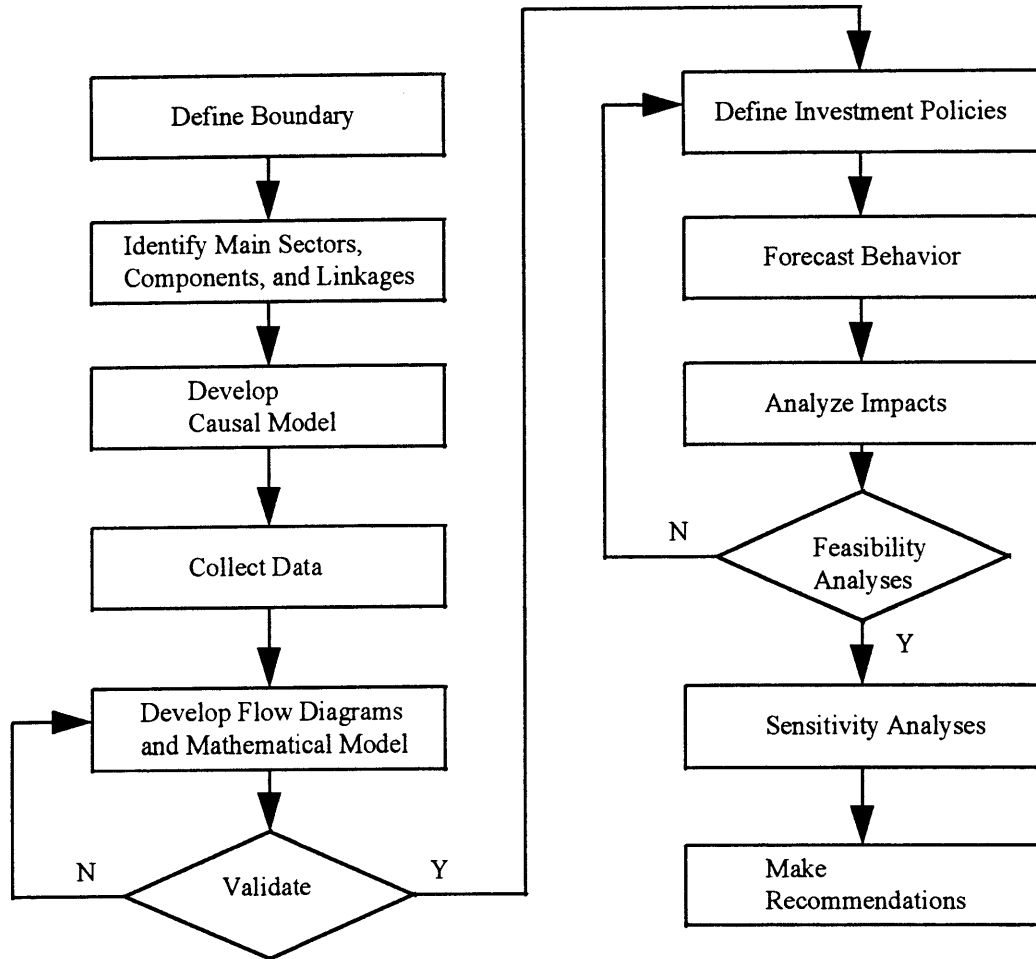


Figure 3.1 Flow Diagram of Method of Approach

3.2.1 System Boundary

Identification of the limits of the impacts of a development strategy is crucial to the overall evaluation of the proposed strategy's benefits or disbenefits.

Most transport investment models delimit the impacted region as a zone extending a given number of miles along the proposed routes. The hypothesis of this research is that the zone of influence extends beyond the immediate region of the investment and that such spatial impacts are experienced through population movements; therefore, the true boundary of the impacts should include the spatially impacted region.

3.2.2 Main Socio-Economic Factors

The behavior or economic performance of any region is the outcome of the dynamic interactions among the socio-economic endowments of that region. The improvement of the region through investments begins with an identification of the main socio-economic factors and how they affect one another to produce the regional performance. The main sectors and linkages are at least determined at this stage.

3.2.3 The Causal Model

The hypotheses of the behavior of a region are formalized through the development of signed di-graphs. The directions of the impacts -- positive (+) or negative (-) -- and feedback structures for the main variables of the domain sectors of the economy are graphically illustrated. The grasp of the complex phenomenon of economic growth is indeed overwhelming when viewed totally. Thus, the causal diagram phase should show the subdivision of the total problem into subsectors and components so that the forces that produce sectoral behavior can be examined. Then, from an understanding of the sectoral performances, linkages among sectors are identified to produce the total causal model.

3.2.4 Data Base

In many developing countries, the complaints of inadequate of data are quite vocal, but very often little is said about what data are needed or in what manner they should be collected and structured for socio-economic planning. As evidenced by the position of the data step in the method of approach after the development of the causal diagram, one begins to appreciate what type of data is critical for an effective analysis of the region's performance. The data base is of course fundamental to the analysis, and, therefore, needs to be collected and utilized in an effective manner.

3.2.5 Flow Diagram and Mathematical Model

The ultimate objective of the development of the model is to be able to quantitatively evaluate the impacts of a proposed investment. The causal diagram, even though very useful, is inadequate for this task. However, as soon as feasible (i.e., all the defining variables are present in the causal diagram), the signed di-graphs are converted into flow diagrams from which mathematical equations are developed, as explained in Chapter 2.

3.2.6 Model Calibration

The mathematical model is then tested for significant (i.e., the ability to replicate past performance). Or, where an interdisciplinary group is involved in the development process, the model is opened to criticisms and inputs from such group. Calibration is an interactive process (i.e., formulation and simulation) and continues until the structure and output of the model is proved useful.

3.2.7 Definition of Policies

Investment strategies in developing countries for poorly accessible rural regions vary from a piecemeal approach to a comprehensive, well-planned and funded project. These approaches are rationalized into three main investment strategies -- (1) Do Nothing, (2) Investment in Roads Only, and (3) Investment in Roads, Drainage, and Irrigation, which are analyzed for their impacts on the study region.

3.2.8 Forecast Behavior

The impacts of each investment are then traced to equilibrium (i.e., to the time at which no further growth in production results from that policy), through the technique of simulation. Simulation technique provides explicit information on the timing of the impacts, a characteristic that is not found in any of the traditional approaches.

3.2.9 Analyses of Imapcts

The traditional net present value method will be used to determine the economic (i.e., quantifiable monetary) impacts of the tested policies over the viable life of the infrastructure provided. In addition to the economic analyses, the impacts on income, demography, etc., will be evaluated in order to determine that strategy or policy with the least negative benefit to the region.

3.2.10 Feasibility Analyses

All policies must satisfy the economic criteria of a benefit/cost ratio of one or greater and a positive net return on investments over the analysis period (i.e., the viable life of the project), in order to be considered feasible. This condition is placed, since for all

intents and purposes it is the one condition that almost all financiers or decision makers insist on before funding is even considered.

3.2.11 Sensitivity Analyses

Feasibility of investment strategies is based on the economic analyses and socio-economic indicators (i.e., benefit/cost ratio, income per capita, etc.); but these indicators are the outcome of the hypotheses and estimates of the behavior and costs of the real activities. Even though every effort is made to calibrate past behavior, changes in behavior and costs in the future may significantly influence impacts, and therefore feasibility.

Sensitivity analyses provide a measure of understanding of the severity of these future impacts, given changes in key socio-economic factors. For that reason, sensitivity analyses are performed to identify the variables that need to be monitored more closely during and after planning and implementation.

3.2.12 Conclusions and Recommendations

Finally, the main characteristics of the research will be highlighted. Recommendations of an investment strategy will be based on a combination of economic feasibility and the strategy that provides the least negative nation and regional impacts.

3.3 Development of the Causal Model

3.3.1 The Main Hypotheses

The hypothesis of the model formulation is that investment is not spatially neutral; that is, decisions taken in any of the regions (developed or underdeveloped) will eventually

impact other regions of the county. The question is how far reaching and diffused would the impacts be? The degree of the spatial impacts will depend on the baseline socio-economic characteristics of the specific county under consideration. That is, in counties where there are significant regional disparities (in terms of job opportunities and income), there is a greater likelihood for shifts in population than in counties with more equitable distribution of development. However, most less developed regions can be typified as agriculturally based or rural economies, in which there are a few or even only a single well developed urban center, and the remainder of the region experiencing different levels of development as measured by population density and socio-economic infrastructure such as schools, electricity, transportation, drainage, and irrigation, etc.. Furthermore, the urbanized centers are generally the attractors of population because of their relatively higher income per capita, better social infrastructure, and perceived greater job prospects, as evidenced by time-series demographic data of most developing countries.

Thus, the boundary of influence of the investment may be defined as the immediate region in which the investment is made and the regions that will possibly be affected by in or out-migration as a result of the impacts of such investments. This boundary and the hypothesized socio-economic characteristics and interactions of the impacted regions are schematically illustrated in Figure 3.2.

The hypothesis of Figure 3.2 is that a poorly developed region (as measured by production level, income per capita, unemployment rate, and accessibility) will lose population to more developed regions of the county, and this migration to urban centers defines the impacted system boundary.

The simplified block diagram in Figure 3.2 shows the subdivision and main variables of the sectors of the impacted regions that dynamically interact to produce the regional socio-economic characteristics of unemployment rate, jobs, income per capita, and production rate. It also implies that, if nothing else, land availability will eventually constrain regional growth and output.

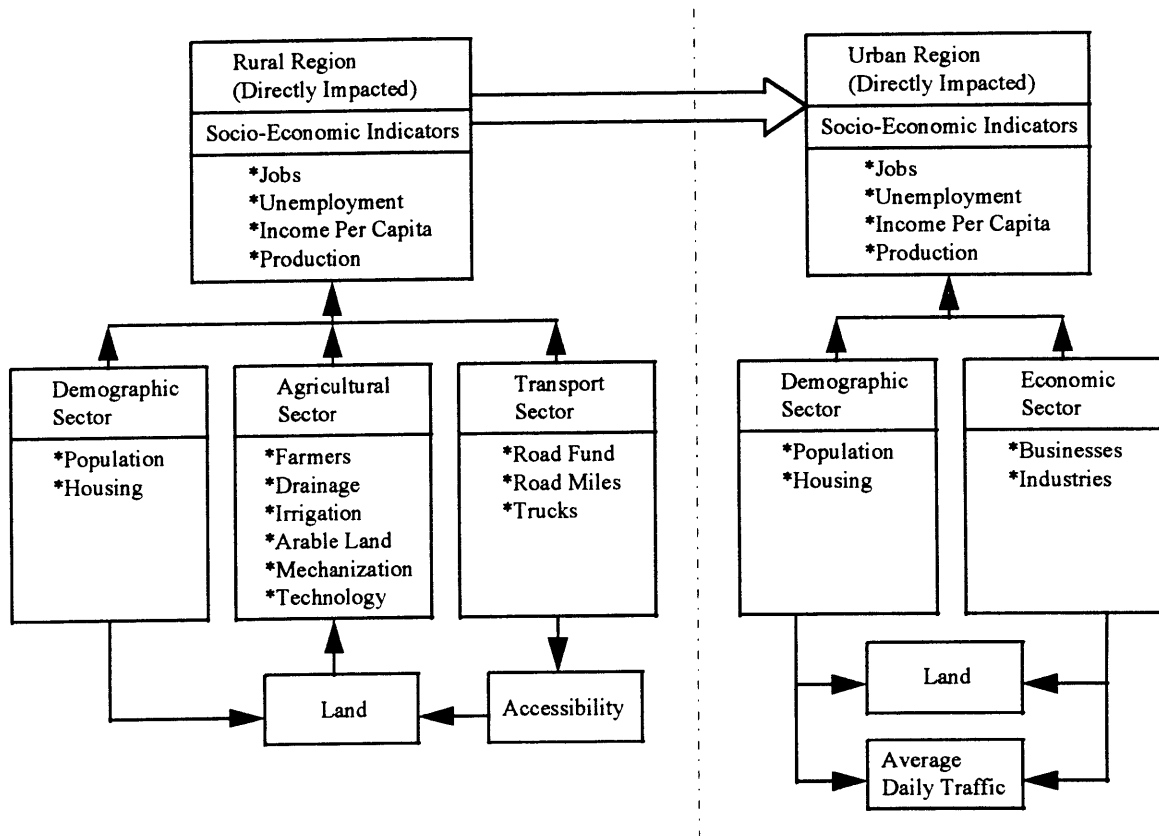


Figure 3.2 Simplified Block Diagram Showing Linkages of the Main Sectors of the Economy

The rural region (i.e., the region directly impacted through investments) is conceptualized as having three main sectors, as shown in Figure. The demographic sector -- whose main components are population and housing -- impacts unemployment (through labor force) and land availability, respectively. The agriculture sector -- whose main

components are farmers, drainage and irrigation, arable land, mechanization and agricultural technical inputs -- impacts production rate, yield per acre, job opportunities and profitability. Finally, the transport sector -- whose main variables are road funds, road network miles, and trucks -- impacts regional accessibility and after production loss.

Now, recall that objective of the developed model is to investigate a strategy in transport and related investments in rural regions that provide the most beneficial direct and spatial impacts. Furthermore, spatial impacts were defined as the shift in population due to differences in regional socio-economic characteristics measured primarily by differences in unemployment rates. Therefore, the main interest in the urban region (i.e., zones to which population is attracted) is its perceived employment characteristics. As such, the urban region is aggregated into only the demographic and economic sectors -- the main determinants of unemployment rates. The demographic sector, whose main components are population and housing, determines the labor force and housing stock of the region. The economic sector, whose main components are business and services, determines the job opportunities of the region. Both sectors impact land availability and traffic generated.

3.3.2 The Causal Model

Figure 3.2 presented the simplified but definite linkages that exist between the major sectors of an economy. In the following sections, the model is presented in more detail so that the causal relationships between the system elements can be understood. The dynamic structure of the model is illustrated using the di-graph concept (or causal model), since it is more convenient to show the direction and the polarity of impacts among

variables. First, the main feedback loops that underlie the sectoral behavior are developed; then the sectoral loops or submodels are synthesized to form the hypothesized causal model of the impacted region.

The Rural Region: Demographic Sector

The demographic is presented by the population and housing components. The regional population level determines the labor, unemployment rate, and income per capita of the region, and exerts a strong influence on the housing component and land conversion from agricultural production to housing use.

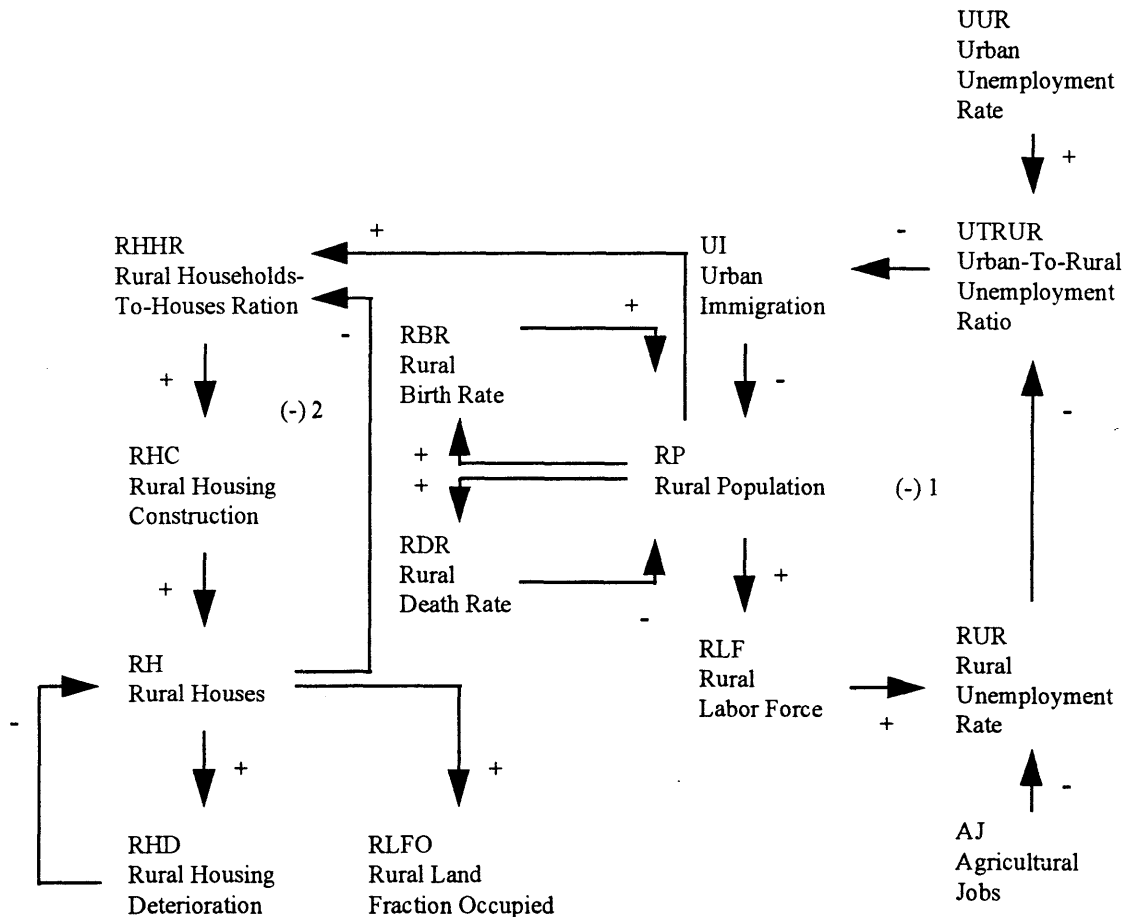


Figure 3.3 The Causal Diagram of the Demographic Sector and Its Two Main Components: Population and Housing

Figure 3.3 shows that demographic sector has two main feedback loops underlying its dynamic structure: (1) a population movement loop (loop 1), and (2) a housing construction loop (loop 2). Loop 1 (Rural Population RP, Rural Labor Force RLF, Rural Unemployment Rate RUR, Urban To Rural Unemployment Ratio UTRUR, and Urban In-migration UI) shows that population movement is governed by the relative unemployment rate (UTRUR) between the rural and urban regions. The forces result in a negative feedback loop, indicating stability in the rural population level in the long run (i.e., urban in-migration will be neutralized when the two unemployment rates are equal), and population growth will be dependent only on birth and death.)

Loop 2 (Rural Houses RH, Rural Households to House Ratio RHHR, and Rural Housing Construction Rate RHC) shows that the housing level is constrained by the housing demand exerted by the rural population level and the housing stock of the rural region. An outflow of rural population relieves the rural housing needs, thereby reducing the impact of housing on the rural land fraction devoted to housing (i.e., a positive impact for agricultural production). This is also a negative feedback loop, since any increase in construction (due to rural housing need expressed by RHHR) increases the housing stock, and in turn, reduces the demand for housing.

The Rural Region: Agricultural Sector

Production and productivity of the agricultural sector are dependent on the following factors: (1) farmers, (2) arable land area, (3) drainage and irrigation, (4) mechanization, and (5) agricultural technique inputs and the cost and level of accessibility of transportation (to be discussed in the Transport Sector). The rate of growth of this

sector is influenced by the rate at which arable land is brought under cultivation, while the land area under cultivation determines the socio-economic performance of the region through the number of “agricultural jobs” and “production rate” variables. Figure 3.4 shows that the dynamic interaction of people, land, machine and economic infrastructure of the agricultural sector results in five main negative feedback loops.

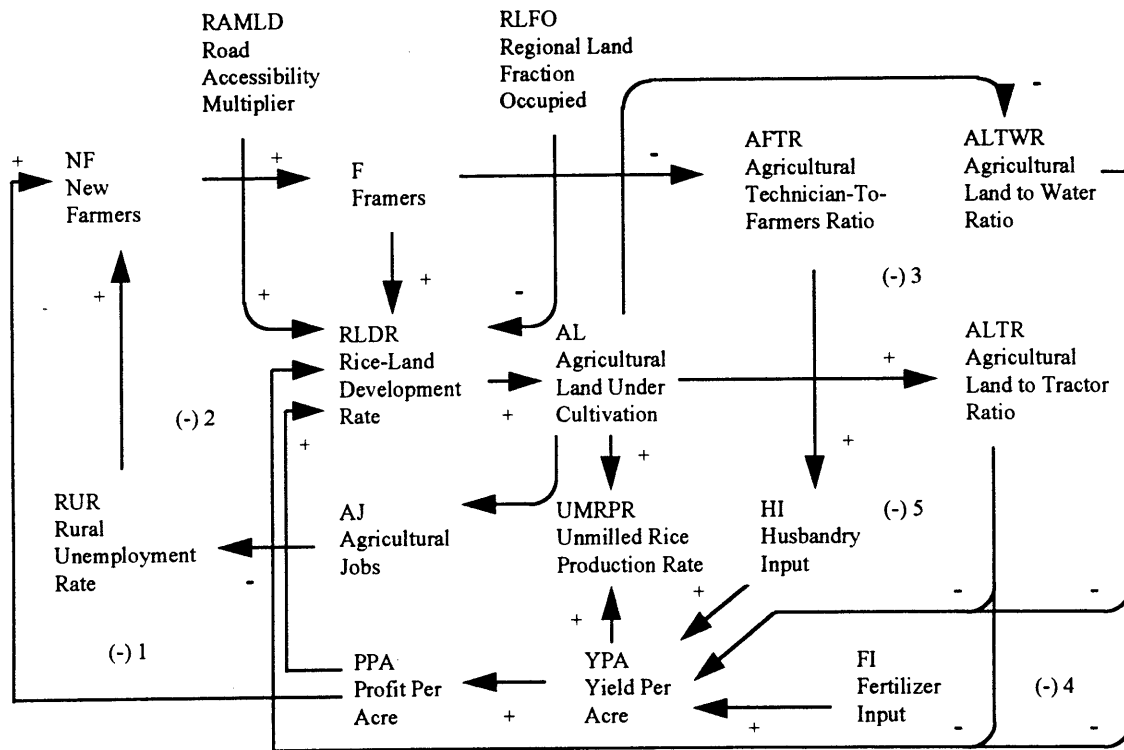


Figure 3.4 Causal Relationships within the Agricultural Sector

Loop 1 (Farmers F, Rural Land Development Rate RLDR, Agricultural Land Under Cultivation AL, Agricultural Land To Water Ratio ALTWR, Yield Per Acre YPA, and New Farmers NF) shows the impacts of one of the most important economic infrastructures (i.e., drainage and irrigation, represented by the variable Agricultural Land To Water Ratio ALTWR) on the amount of agricultural land cultivated. This is a negative feedback loop which limits the acreage cultivated to a level which can be feasibly irrigated

by the available water and drainage infrastructure of the study region. The influence is that road (probably the most important economic infrastructure) is not the only answer to production expansion. For instance, as the acreage of cultivation increases, the ratio ALTWR increases, implying drainage and irrigation availability per acre drops, and hence negatively impacts yield, profit and the number of people turning to farming. These factors, in turn, negatively impact land development rate, resulting in lower acreage under cultivation.

Loop 2 (Farmers F, Agricultural Technicians-To-Farmers Ratio ATFR, Husbandry Inputs HI, Yield Per Acre YPA, Profit Per Acre PPA, and New Farmers NF) shows that the impacts of technological inputs or farmers education, as presented by the variable ATFR, on production and productivity.

As technical advice to farmers (represented by the number of agricultural technicians) increases, it is expected that yield will be positively impacted, and therefore the overall production will also increase. This is a negative feedback loop, since an increase in yield means an increase in profits, which positively impacts the number of framers; and this reduces the agricultural technicians-to-farmers ratio ATFR. In a similar manner, Loops 3, 4, and 5 show the direct impacts of drainage and irrigation ALTWR, and mechanization ALTR on rural land development rate RLDR; that is, the perceived availability of these services speeds up the rate at which “new” or virgin land is brought under cultivation.

The Transportation Sector

More and more, transportation has come to symbolize road transportation, which is especially the belief in agricultural development projects. This may be so, because every other mode involves intermodal transfers, creating multiple handling, delays and increased costs. In addition, the provision of roads allows for all levels of entrepreneurs (i.e., single operator and/or major firm operating side by side) in the transportation of regional inputs and output. Wherever other modes are involved, they are primarily provided to keep pace with the expansion in production due to the increased accessibility and mobility provided by the improved road infrastructure. In the rural scenario, road transportation is generally perceived to be the main constraint to economic growth, and as such it is the focus of the model design. This sector is explicitly represented by the following main components: (1) road fund, (2) total miles of road, and (3) trucks. These components dynamically interact to provide regional accessibility and transport capacity. Figure 3.5 shows that the road transportation sector is defined by three main feedback loops.

Loop 1 (Demand For Road DFR, Road Construction Rate RCR, Rural Road Miles RROAD, and Road Density RD) explicitly incorporates the demand/supply equilibrium concept of roads in the model. Conceptually, the network of roads needed in a given region depends on the crop type being cultivated (or proposed for cultivation); that is, each crop type is best served by a given configuration or network density. As this “ideal” density is reached, further demand for roads ceases, resulting in an equilibrium demand/supply situation, as illustrated by the negative polarity of the feedback loop.

Loop 2 (Road Density RD, Road Accessibility Multiplier on Land Development Rate RAMLD, Rural Land Development Rate RLDR, Agricultural Land Cultivated AL,

Agricultural Production Rate APR, Truck Trips TT, Road Deterioration Rate RDR, and Rural Road Miles RROAD) shows the impacts of increased network miles on land development rate on the after production loss. An increase in road density increases the accessibility of the region, which should positively increase the rate at which “new” land is brought under cultivation, and therefore increase the overall output of the region. An increase in transport capacity (i.e., an increase in the mobile stock -- trucking fleet) would result in increased after production losses. Thus, the road infrastructure alone is not the complete answer to overall output rate of the region.

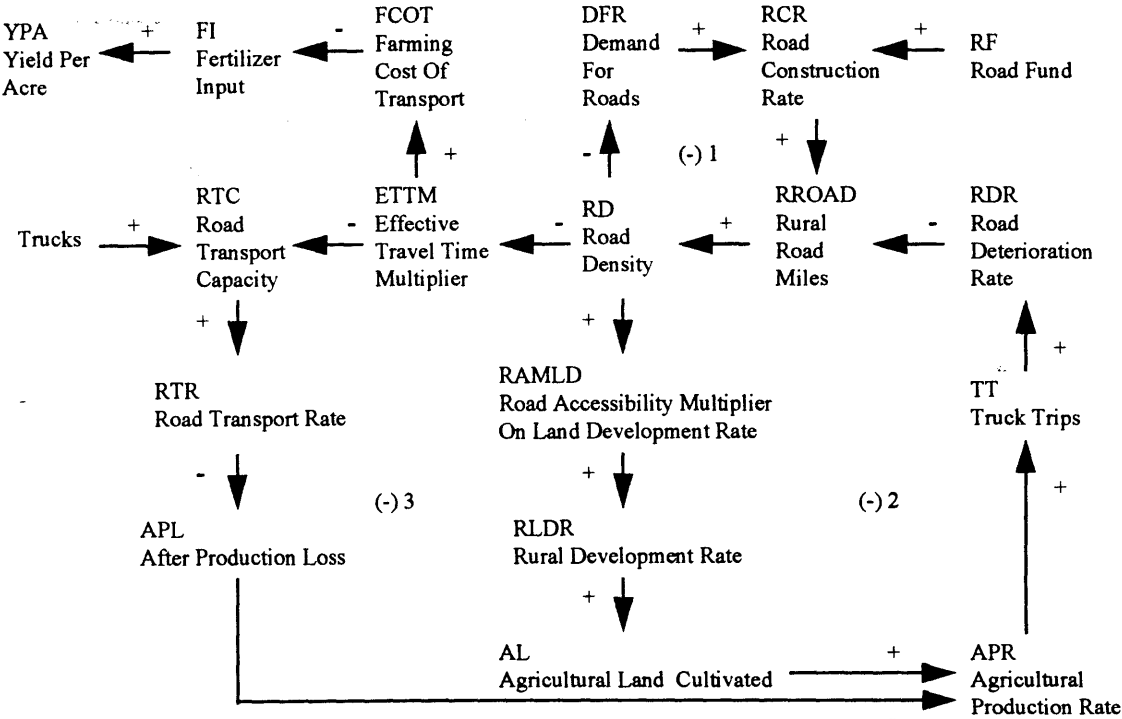


Figure 3.5 Causal Relationships within the Transport Sector

Loop 3 (Road Density RD, Effective Travel Time Multiplier ETTM, Road Transport Capacity RTC, Road Transport Rate RTR, After Production Loss APL, Agricultural Production Rate APR, Truck Trips TT, Road Deterioration Rate RDR, and

Rural Road Miles (RROAD) shows the impacts of improved road network on road transport capacity and after production losses. Improvements in the road network should reduce the effective travel time of the region, and a reduction in travel time results in an increase in transport capacity of the region due to shorter return trip time. Likewise, an increase in transport capacity reduces after production loss. This is a negative feedback loop, which also indicates that as after production loss reduces, overall regional agricultural production increases; and an increase in production results in an increase in truck trips, which in turn reduces the road network "effective" miles. Furthermore, the significance of a good maintenance policy is also implied in this loop (i.e., it is not enough to only construct adequate network, but maintenance of the network must also be adequately provided if overall production is to be sustained). This loop also attests to dynamic interactions between the transport and agricultural sectors -- through the road accessibility multiplier, agricultural production rate and the road deterioration rate variables.

The Urban Region: Demographic Sector

The hypothesis is that spatial impacts are due to shift in regional migration which is caused by the perceived differences in unemployment rates or the ability to secure employment in a given region. At this stage, one possible approach to complete the modeling process is to use the current or projected unemployment rate of the urban region. This approach, however, would remove the dynamic impacts that would result in the socio-economic characteristics of the regions affected by a significant shift in the population. A change in population not only affects the unemployment rate, but also the

demand for housing, labor availability, regional income per capita, etc., as shown in the previous submodels developed so far. Thus, it becomes necessary to use a “dynamic” or updated urban unemployment rate, which can only be done by explicitly incorporating the sectors that produce the unemployment.

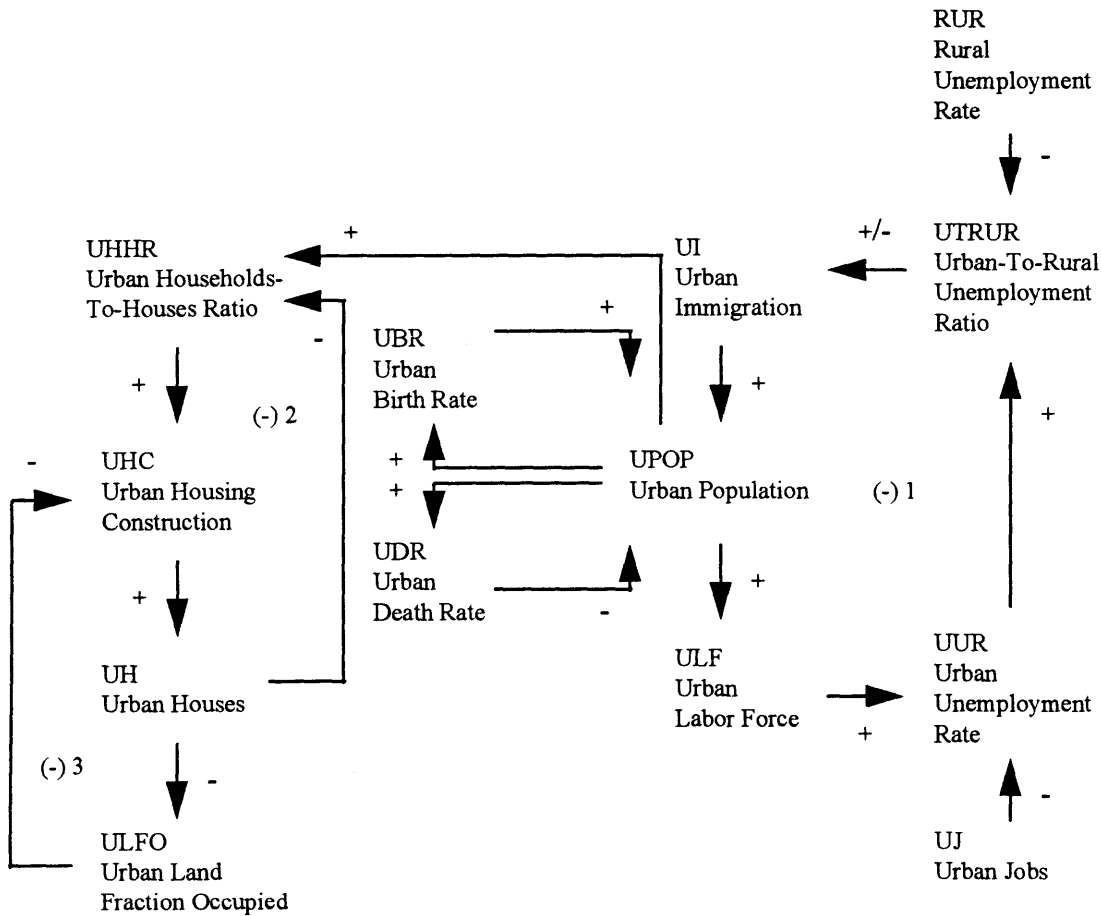


Figure 3.6 The Causal Relationships within the Demographic Sector

Figure 3.6 shows that the demographic sector has three main feedback loops with the underlying structure similar to that of the rural demographic sector (as it should be, since the population level of any region depends primarily on the same variables -- birth, death, and migration rates); the only difference is in the housing construction loop, where land availability in the urban region creates an additional constraint to housing rate of

growth not experienced in sparsely populated rural regions. The explanation of the loop is similar to that of the rural region.

The Urban Region: Economic Sector

The socio-economic activities of the urban region create the job opportunities of the region. The degree of disaggregation of the socio-economic activities into manufacturing, service industries, etc., depends on the region being studied and the cost involved for the disaggregative studies.

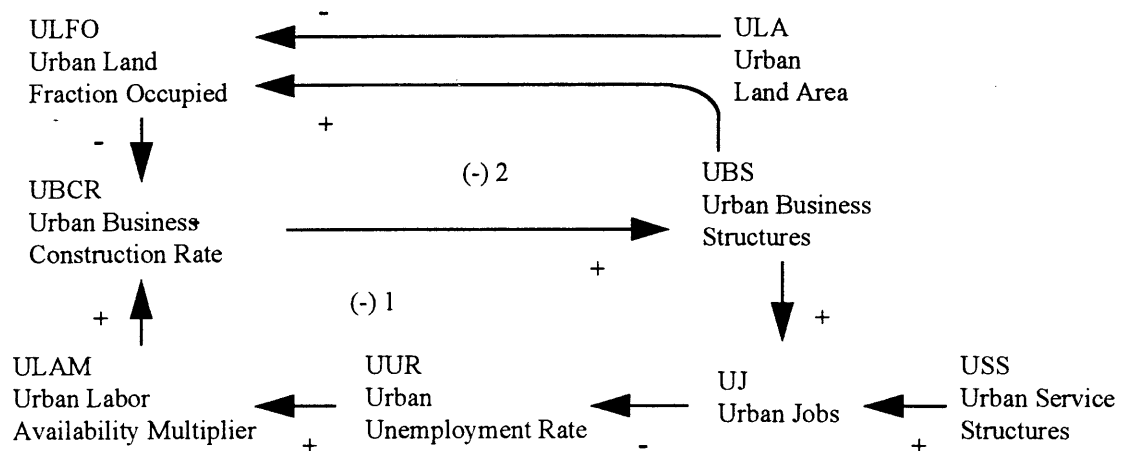


Figure 3.7 The Causal Relationships within the Economic Sector

Figure 3.7 shows the main feedback loop (Urban Business Structures UBS, Urban Jobs UJ, Urban Unemployment Rate UUR, Urban Labor Availability Multiplier ULAM, and Urban Business Construction Rate UBCR) underlying the dynamic structure of the sector. Conceptually, as the number of business structures increases, the job opportunities increase, leading to reduced unemployment rate, which in turn reduces the labor force available for further business expansion. This indicates that the feedback loop is negative.

Furthermore, the growth of both sectors (the demographic and economic) is governed by land availability.

3.3.3 Synthesis of the Submodels

The premise of the model development is that there are definite linkages, causality and feedback relationships between the major sectors of the economy; and that investments in any of the sectors will impact the other sectors in the long run. Specifically then, the synthesis or linkage of the sectoral submodels explicitly accounts for the causality, feedback and catalytic impacts of investments in transport and other economic infrastructure on production (i.e., the economic sector) and on shifts in population (i.e., the demographic sector).

Figure 3.8 shows the simplified synthesized causal model of the impacted regions, in which only the main loops that influence intersectoral impacts are included. The important inter-sectoral impacts are recognized through the following variables: (1) Agricultural Land Development Rate ALDR, (2) After Production Loss APL, (3) Agricultural Jobs AJ, (4) Urban To Rural Unemployment Ratio UTRUR; and (5) Urban In-Migration UI. The first three variables link the sectors of the investment region, while the last two variables link the rural region with the urban region, thus providing explicitly for the spatial impacts.

The synthesized causal model of the impacted regions provides the framework for the collection of the appropriate data base and the development of the quantitative mathematical model for the economic analyses of a given investment policy.

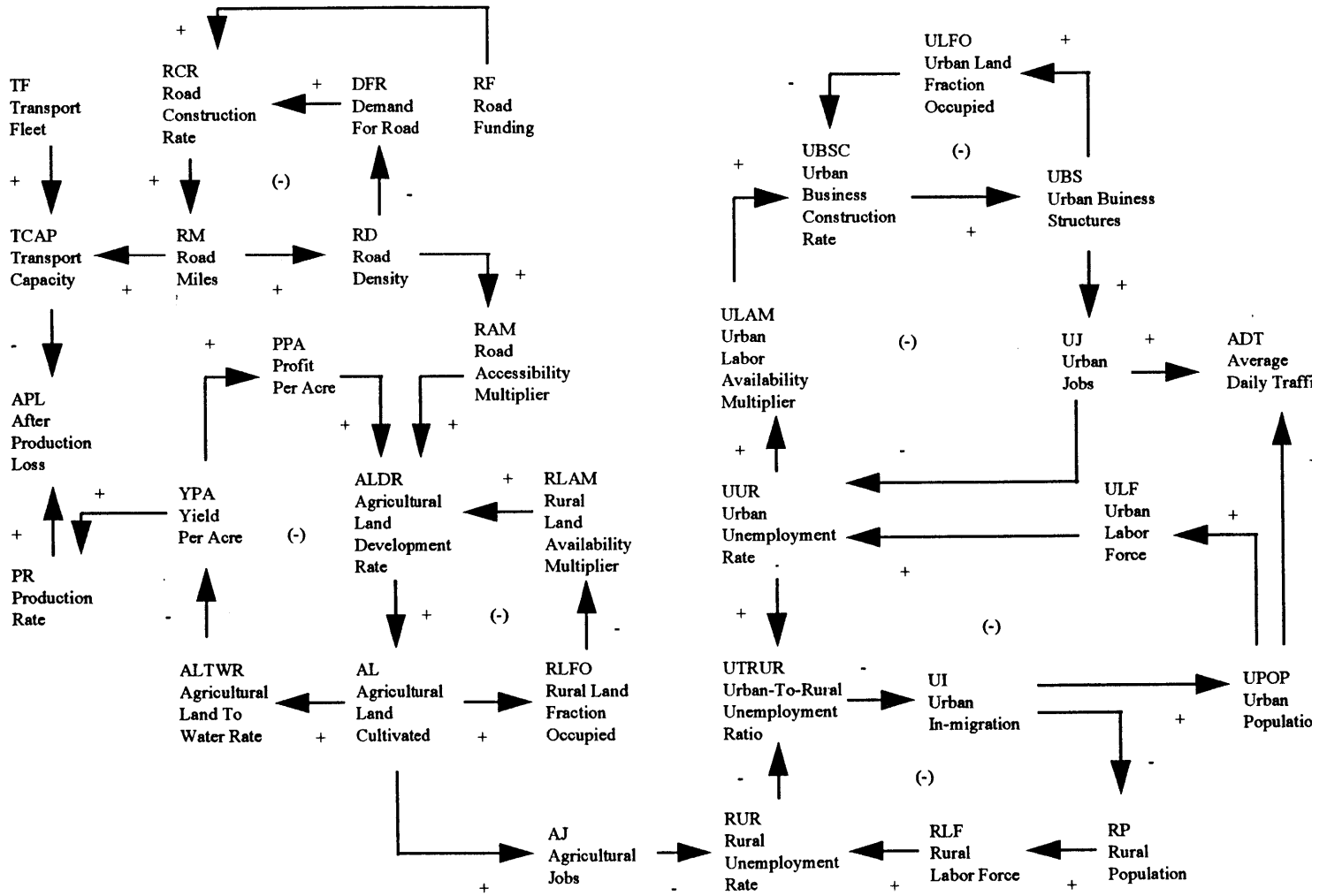


Figure 3.8 The Comprehensive Causal Model Showing Main Feedback Loops

Chapter 4

Case Study of Chang-Hwa County, Taiwan

The foregoing chapters have presented the rationale and concepts considered necessary for a comprehensive evaluation of rural transportation and related investments in developing and poorly accessible agricultural regions in developing countries. What remains to be done now is to apply these concepts and techniques in a real world scenario. The County of Chang-Hwa, Taiwan, is chosen for the case study because (1) it is typical of LDRs in which accessibility is perceived to be a main constraint to accelerated economic growth and national integration; (2) large sum of money are annually allocated for the expansion of the transportation sector; and (3) the county's professed economic density is in the development of its agricultural potentials.

This chapter consists of four sections. Section 4.1 provides a brief background of the geographic, demographic, and economic characteristics and also the agricultural objectives of the county. Section 4.2 provides a detailed discussion of the socio-economic characteristics of the study region directly impacted by the investment and the region that is assumed to be spatially impacted under any given investment strategy. In Section 4.3, the model's levels, main assumptions and equations are presented and discussed. In Section 4.4, the model calibration is undertaken -- a ten year period of basic data is used to develop a working model on which policy analyses will be undertaken in Chapter 5.

4.1 Background

4.1.1 Geography: Location

Chang-Hwa County is located on the west-central coast of Taiwan. It is bounded on the east by Nan-Tau County, on the south by Yuen-Lin County, on the west by the Taiwan Channel, and on the north by Tai-Chung County. Figure 4.1 shows the main regions and geographic location of Chang-Hwa County to its neighbors.

4.1.2 Geography: Land Topography

Chang-Hwa County consists of three natural regions: (1) a coastal plain; (2) an intermediate peneplain; and (3) the highlands.

The coastal plain which comprises the coastal and peripheral areas, is rich in alluvial soils, flat and low-lying (four to five feet below the sea-level at the tides), and subject to deluge and drought. Costly sea defense, drainage and irrigation works are prerequisites for agriculture.

The intermediate peneplain situated immediately to the east of the coastal plain, and consisting a part of the Interior Areas, is a broad north-south plateau of flat and soils. Part of this region is Yien-Pu (the Intermediate or Western Shi-Fu in the Pa-Chang Area), which is subject to leaching, sparsely covered with grass, and suited only to very extensive farming. The remainder is dense equatorial forests which contain greenherat, purpleheart, mora, crabwood and wallaba (i.e., commercial species of wood).

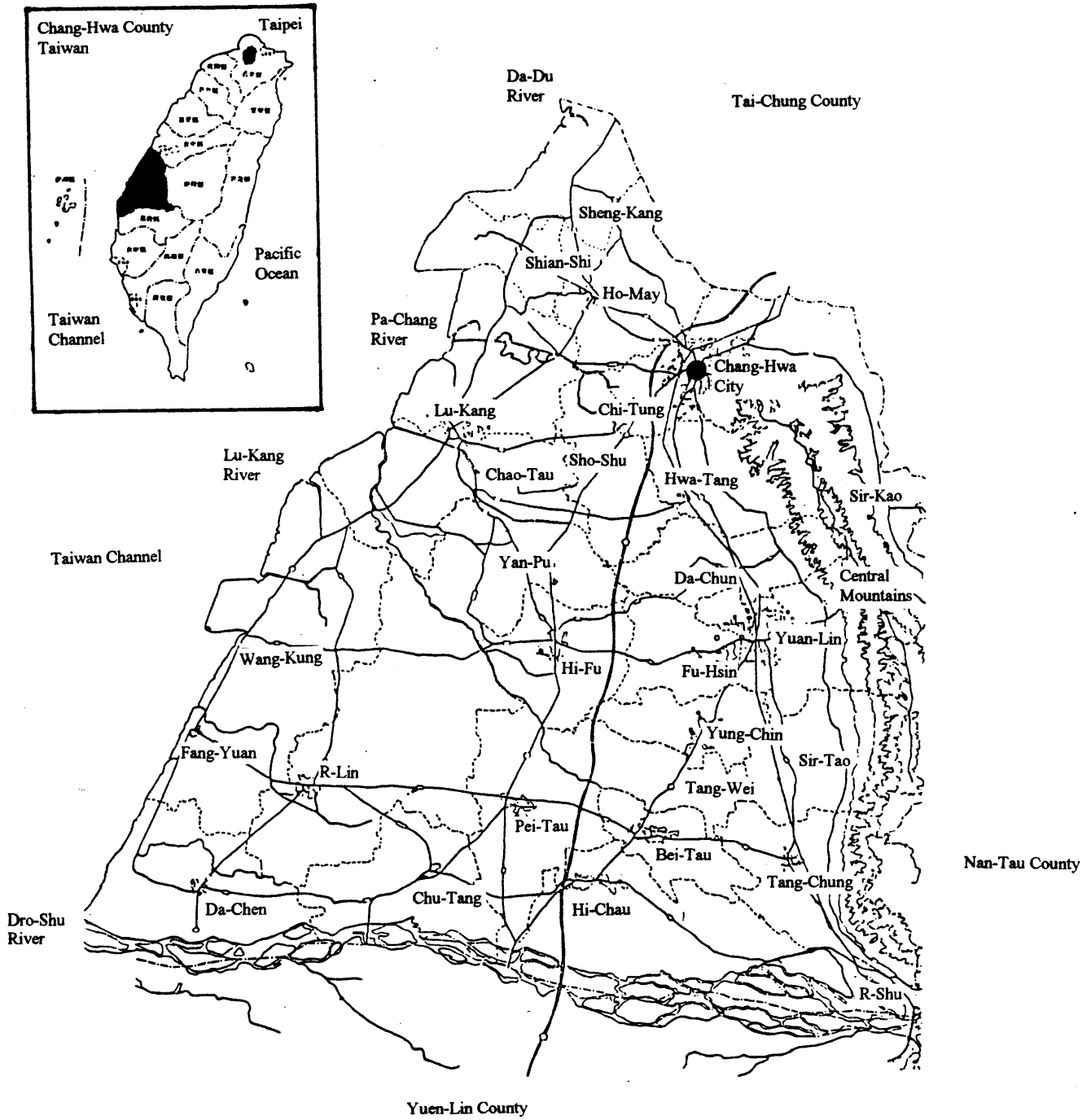


Figure 4.1 Map of Chang-Hwa County, Taiwan

The highland, situated immediately to the east of the intermediate peneplain, and consisting the remainder of the Interior Areas, is by far the largest of the three natural regions and is for the most part hilly, mountainous and intersected by rivers. It is known for its spectacular scenery. It is mostly covered with dense equatorial forests except for a small area (about 45 square miles) located in the southeast which is Pei-Tod (the Southern Shi-Fu).

4.1.3 Geography: Rivers

Chang-Hwa County's land platform is cut by numerous rivers which flow generally in a westerly or northerly direction to the Taiwan Channel from the highlands, through the intermediate peneplain and the coastal plain.

The four major rivers which all flow in a westerly direction are: the Da-Du, which is located along Chang-Hwa County's northern border with Tai-Chung; the Pa-Chang, which is located to the south of the Da-Du and runs generally parallel to it at distance varying from 3 to 5 miles; the Lu-Kang, which is located to the south of the Pa-Chang and runs generally parallel to it at distances varying from 5 to 12 miles; and the Dro-Shu, which is located about 5 to 16 miles to the south of the Lu-Kung.

The Dro-Shu is the largest river (approximately 2 miles wide at its mouth). It originates near the Central Mountains border, flows a distance 40 miles to the Taiwan Channel and has many large tributaries.

4.1.4 Geography: Climate

Chang-Hwa County has an equatorial climate with high humidity, a high but variable rainfall, and medium to high temperatures. On the coastal region, the high humidity is tempered by the cool northwest sea breezes. The annual rainfall varies from about 65 to 105 inches. Temperature ranges from 65 to 95 degrees; and there are 11 1/2 to 12 1/2 hours of daylights.

The coastal region has two wet and two dry seasons. The first wet season usually occurs from April to August, and the first dry season from August to mid-November. The second wet season normally occurs from mid-November to January, and the second dry season from January to April.

The forested area has a more even rainfall throughout the year. The Ten-Chung have a well-marked dry season from October to February, while the wettest months are from May to August. The county lies to the central of the typhoon belt and is affected by the typhoons that periodically sweep the East Asian regions.

4.1.5 Land: Area and Distribution

Chang-Hwa County's land area is about 1350 square miles distributed roughly as follows: 70 square miles (5.2%) in the coastal region; 180 square miles (13.3%) in the intermediate region; and 1100 square miles (81.5%) in the interior region. The coastline is 36 miles long.

4.1.6 Economy: Production and Distribution

Production here refers to the number of tons of commodities produced annually that have to be exported to the other counties or that have to be transported from one

geographic area to another within the county. Locally consumed products, to the extent feasible, are included.

Additionally, two types of production are distinguished: (1) gross production; and (2) net production. Gross production includes, whereas net production excludes, sugar cane, rice paddy, and greens. Net production includes products derived from sugar cane, rice paddy and greens (i.e., sugar, rice, and green-grocery).

Existing annual production is estimated to total on the order of 10,000,000 tons gross, or 4,00,000 tons net. The large difference between gross and net production (6,000,000 tons annually) indicates the huge quantities of waste products resulting from processing sugar cane, rice paddy, and greens. Available gross and net production figures by major product groups for the year 1985 are given in Table 4.1 and are as follows.

Table 4.1 Gross and Net Annual Production By Products, 1985

	Gross Production (thousand of tons)	% of Total	Net Production (thousands of tons)	% of Total
<u>Agriculture</u>				
Sugar Cane	3,145	32	--	--
Rice Paddy	169	2	--	--
Greens	4,988	52		
Other Crops	166	2	166	4
Livestock	7	<1	7	<1
Fishing	17	<1	17	<1
Forestry	182	2	182	5
<u>Manufacturing and Process</u>				
Greens and Related	--	--	2,593	66
Sugar and Related	431	4	431	11
Rice and Related	110	1	431	3
Other	452	5	452	11
Total	9,677	100	3,958	100

Greens and sugar cane dominate gross production. Greens accounted for 4,988,000 tons (52%) of the 1985 gross production. Sugar cane accounted for 3,145,000 tons (33%) of the 1985 gross production. Rice accounted for 169,000 tons (2%) of the 1985 gross production.

Greens products dominate net production. They accounted for 2,593,000 (66%) of the 1985 net production. Sugar cane and related products accounted for 431,000 (11%); rice and related products accounted for 110,000 tons (3%).

These three products -- sugar, rice, and greens -- accounted for over 8,000,000 ton, almost 90% of 1985 gross production, and over 3,000,000 tons, almost 80% of 1985 net production.

When the geographic distribution of the production areas for sugar cane, rice paddy, greens and their related products are examined, two items of importance stand out. First, the production areas of all three products are in close proximity to Chang-Hwa City (county's capital). Second, the production areas of all three products occupy relatively small areas of land.

Production yields from areas close to and remote from Chang-Hwa City ("close" being defined as up to approximately 10 miles from Chang-Hwa City, "remote" as beyond 10 miles from Chang-Hwa City) are given in Table 4.2

Areas close to Chang-Hwa City yielded 9,376,000 tons (97%) of the gross production, or 3,667,000 tons (93%) of the net production. Areas remote from Chang-Hwa City yielded 291,000 tons (3%) of the 1985 gross production, 7% of the 1985 net production.

Table 4.2 Gross and Net Production By Areas, 1985

	Gross Production (thousand of tons)	% of Total	Net Production (thousands of tons)	% of Total
<u>Areas Close to Chang-Hwa City</u>				
Coastal Area	254	3	251	6
Pa-Chang Area	4,134	43	823	21
Dro-Shu Area	4,988	52	2,593	66
Subtotal	9,376	98	3,667	93
<u>Areas Remote from Chang-Hwa City</u>				
Other Interior Areas	291	2	291	7
Total	9,667	100	3,958	100

Additional to the total area occupied by the principal crops, substantial areas are occupied by related land uses such as pasture, gardens, dams, canals, roads, houses, factories, mills, schools, and community buildings, processing facilities, and other economic activities. But, even with all these additional areas, it is clear that only half part of the total 1350 square miles of Chang-Hwa County is actually developed.

Although exact figures are not available, it seems that a maximum of about 500 square miles (37%) of the total land area is intensively developed, and about 850 square miles (63%) is undeveloped -- expect for isolated pockets, most of which are developed on an extensive basis. It appears that over 90% of the total gross and net production is obtained from less than 40% of land, and that almost all of this production takes place on land within a 25 or so miles from Chang-Hwa City.

4.1.7 Human Resources: Population and Distribution

The geographic distribution corresponds closely with the distribution of production, with some notable exceptions. The Hwa-Tang area, for example, contains less than 5% of the total population, produces over 40% of the total net production and over 50% of the total gross production, an imbalance that reflects the high productivity of the rice farming and processing operations. The centers of Chang-Hwa and Yuan-Lin (the second important center of the county) on the other hand contain proportionately more population than gross production. With these exceptions, the population generally corresponds closely with production regions, and, as would be seen later, with accessibility by roads.

The 1985 census shows Chang-Hwa County's population at about 740,000. About 640,000 persons (86% of the population) live and work in the interior, and about 100,000 (14% of the population) live and work in the Coastal Area. The metropolitan area of Chang-Hwa City, including the vicinity within 12.5 miles from the center of the city, contains more than 50% of the population. Table 4.3 gives the breakdown of the Chang-Hwa Metropolitan area population.

Table 4.3 Population of Chang-Hwa Metropolitan Area, 1985

	Persons	% of Total Population
Chang-Hwa City	164,000	23.4
Chang-Hwa Environments:		
East Coast	92,000	13.1
East Bank	36,000	5.1
West bank	25,000	3.6
West Coast	53,000	7.6
Total	370,000	52.8

The population of Chang-Hwa County in 1960 was 375,000 persons; in 1975, 560,330; and had risen to 740,000 in 1985. This represents an average annual rate of growth of 2.9% over the past decade. Registration data has indicated that birth rate has declined slightly from 42 births per thousand per year in 1975 to 37 per thousand in 1985. This decline has been accompanied by a reduction in the death rate from 9.5 deaths per thousand per year to 8.5 per thousand.

A survey of the manpower requirements and labor conducted by the Executive Yuan in 1980 covered all of Chang-Hwa County except the very sparsely populated region. At the time of the survey, the labor force was given as 174,772 persons, with participation rates for males 14 years and over of 81.8% and for female of 29.3%. Based on similar participation rates, the labor force for 1985 is given as 225,000 persons in 1985. A similar survey for work places indicates an unemployment rate of over 20% in 1985.

The literacy rate in Chang-Hwa County is quite high. An estimated 90% of the children receive the basic education, which is nine years of compulsory instruction, including the full primary course, plus three years in junior high school.

4.1.8 Transportation: Available Modes

The modes of transport available in different geographic areas reflect, and is a reflection of, the geographic distribution of total passenger and freight loads. The principal means of transport to Chang-Hwa City from different parts of the county, divided into three categories as follows:

(1) Category 1: includes areas from which road is the principal means of transport;

- (2) Category 2: includes areas from which road is the principal means of transport, but a railroad must be also used;
- (3) Category 3: include areas from which road via trail is the principal means of transport(vehicular transport from these regions can be accomplished only by motorcycles or conditional truck; driving is extremely difficult and slow, and in many places is only possible in fair weather).

With these different modes of transport, one would expect that there would be one single agency responsible for the planning and coordination of all aspects of the transport system. The responsibility for each mode of transport is divided and handled by a heterogeneous mix of agencies. Thus, there is a lack of coordination.

Road transport, undoubtedly the most important mode in terms of connectivity and impact on agricultural development, is discussed in some detail. The road subsystem carries almost all of the total passenger and load (98% of the estimated 1985 passenger miles), and a substantial proportion of the total freight load (34% of the estimated 1985 ton miles). It carries all of these loads in the Interior Coastal Area and minimal loads in the Coastal Area.

Roads carry passenger and freight loads to and from main transport terminals (thus, completing door-to-door out-of-region trips which involve other transport modes). The county road network which carries these loads consists of about 147 miles of paved roads and unpaved trails.

4.1.9 Commodity Flows

The major production flows of sugar, rice, and greens are fairly concentrated and depend on more or less unique modes of transport described below.

A. Sugar

About 93% of Chang-Hwa County's sugar is produced on eleven large and two small sugar estates; the remaining 7% on a number of small cane farms, all located along the Coastal Area between the Da-Du and Da-Chia rivers. The estates run in narrow strips generally westward from the main coastal arterial highway to the swamps at an average width of about 7 miles west of the highway. The swamps are dammed off to provide a controlled water supply for irrigation. The estates range from 1 to 3 square miles in area. It has been estimated that the total length of the irrigation-transport canals on all the estates is well over 50 miles.

Almost all the sugar cane (3,000,000 to 4,000,000 tons) is transported in small flat-bottom steel barges, towed by tractors along the canal to one of the eleven estates. Here, the cane is crushed and sugar and molasses extracted.

Most of the processed sugar (300,000 to 400,000 tons annually) is transported from the estate factories by barges towed by tugs to the Chang-Hwa City. Factories close to Chang-Hwa City use bulk road transporters.

At the railroad station of Chang-Hwa City, the sugar is loaded into a 70,000 ton capacity bulk storage-loader facility. About 30,000 tons annually are retained for locally consumption; the remainder (about 300,000 tons annually) are exported chiefly to metropolitans of Taipei, Tai-Chung, and Kao-Hsiung.

Molasses (100,000 to 130,000 tons annually) is transported in more or less the same as sugar.

Railroad transport is the predominant means used to transport cane, sugar, and molasses from estates to factories, from factories to bulk terminals, and from the bulk terminal to domestic markets.

B. Rice

The flows of rice are quite different from those of sugar because of the very large number and small size of the rice farms. Sugar estates average about 1.5 square miles in area; but most rice farms are less than 10 acres, as given in Table 4.4.

Table 4.4 Acreage of Rice Farms, 1983

Size of Farms (Acres)	% of Farmers	% of Rice Lands
0 - 9	81	43
10 - 49	17	26
50 - 99	1	7
100 and Over	1	24
Total	100	100

While there are 13 sugar estates and a relatively small number of cane farms, it is estimated that the number of rice farms is in excess of 30,000. This means that there are thousands of small flows from rice farms or rice mills; and the estimated annual output from each rice farm is between 3 and 5 tons.

The rice paddy (200,000 to 300,000 tons annually) is moved from the rice farms by trucks or tractor-hauled cart to the rice mills nearby where the husk and rice are

separated. Each year, the autumn crop, which is planted between April and May and produces about 80% of the total yield, is harvested during October, November, and December. The spring crop is usually planted in December and harvested during March and April.

Some of the processed rice is retained by the producers (35,000 to 45,000 tons annually), but most of it (about 80,000 to 110,000 tons annually) is transported from the mills to the warehouse of the Central Region Rice Market Board in Chang-Hwa City. Nearly all of this is transported by trucks except for that from the Dro-Shu Coast, which is transported by railroad.

The Rice Marketing Board is responsible for the storage, remilling, packaging and distribution. It retains a small quantity of the processed rice for local consumption (10,000 to 15,000 annually), and exports the balance (70,000 to 100,000 tons annually), mostly to the Central Region counties.

The basic transport problem of rice framers is the transport of paddy from farm to mills. Many farmers now have to struggle some distance along muddy dams and tracks before reaching a reasonably well-surfaced road. Moreover, they have virtually no possible way of solving this problem on their own. Provision of the necessary access is the task of Government. This is strict contrast to the situation of the sugar producers. They have virtual control over any transport problem that may arise.

C. Greens

The flow of greens and related products are fairly simple compared to those of rice and sugar. Almost all of the greens are farmed at three green-grocery professional districts

in the North -- Hwa-Tang, Lu-Kang, and Sir-Tao -- and transported from there to two processing centers-- Lu-Kang, and Yuan-Lin. Products are transported from processing centers directly to intercounty trans-shipment points and from there to domestic market.

4.1.10 The Relevance of Agricultural Development to Chang-Hwa County's Economy

Funding of major development projects in developing countries should not only be economically feasible, but in consonance with the national development policies, if maximum possible benefits are to be achieved from the investments.

The agricultural sector constitutes the largest productive sector in the economy of Chang-Hwa County. The sector's share of the Gross Production at current factor costs averaged 23%. However, real growth in the agricultural sector has not kept pace with population growth since 1976, resulting in increasing dependence on imported food.

The sluggish growth in agricultural production has been associated with a decline in the proportion of the labor force employed in this sector; that is, from 45% in 1965 to 31% in 1990.

During this period, the shares of the population living in the rural areas have remained fairly constant, implying a substantial increase in rural unemployment and underemployment. With limited employment opportunities in the urban areas due to slow growth in light industries and employment saturation in the tertiary sector, there is a strong need for the development of agricultural production for both domestic and local markets.

Chang-Hwa County's development strategy is directed towards development of the rural sector through the integrated economic and social approach designed to increase

food production and rural incomes, while concomitantly providing selective social services to the rural population.

Stressing the emphasis of agricultural development is the Government's Third Development Plan (between 1993 and 1996), which allots fully one-third of all public and private investments to agricultural activities. This amount is more than double the percentage provided to this sector during the previous Five-Year Plan. The rationale for the new plan is that the majority of its resources over the next four years should be devoted to the productive sector, such as agricultural, since it is seen as the only feasible approach open to Chang-Hwa County to recover from its present economic crisis.

Table 4.5 Basic Socio-Economic Data on Chang-Hwa County, Taiwan (Da, 1993)

<u>Basic Data</u>	
Total Population	832,000 (1993)
Per Capita Income	\$3,400 (1990)
Average Annual Per Capita	
Real GRP Growth Rate	-1% (1985-1990)
% of Regional Income Received	
By Low 20% of Population	4.3% (1975)
Literacy Rate	85% (1987)
<u>Special Data</u>	
Population Growth Rate	2.2% (1982-1992)
% of Population In Urban Area	32% (1985), 40% (1988)
Total Birth Per 1,000 Population	27 (1991)
Total Death Per 1,000 Population	9 (1991)
<u>Trade</u>	
Major Exports	Greens, Sugar, Rice (1992)
Major Imports	Machinery, Fuel, Fertilizer, Food (1991)
<u>Transport Capital Expenditure</u>	
Transport Capital Expenditure as a percentage of Total Capital Expenditure	21.7% (1980), 26.8 (1990)

The potential for expansion and diversification of the agricultural sector is in no doubt; all that is needed is the investment to exploit its resources.

Moreover, emphases on rural oriented project activities are fully in consonance with policy guidance relating to assisting the most economically deprived areas. The rural per capita income in 1990 was estimated at approximately \$3,400, which is considerably below the national per capita income of \$6,700. Table 4.5 provides the basic socio-economic data on Chang-Hwa County.

4.2 The Study Regions

In resource-scare economies, there are no shortage of requests for improved access or other socio-economic infrastructure; the question is generally where to allocate the limited resources in order too obtain the most satisfactory national benefits; or to put it another way, the least negative impacts. Choices are never really clear-out since there are very often conflicts and trade-offs between national goals and economic returns, However, there are definite socio-economic indicators as to where investments might be “seemingly” justifiable. An examination of the distribution of the population and economic activities (i.e., industry and agriculture) in relation to the transportation system and classified arable land provides positive indication as to where transportation and agricultural related investment might be feasible. An analysis of the above figures shows quite clearly that the intensity of economic activities is dramatically curtailed at the end of passable roads, even though the soil is classified as arable beyond the end of the passable roads. That is, the quality of the transport services provided influences both the intensity and extensiveness of the region’s development. However, as previously stressed, no investment is spatially

neutral; but, the impacts of the investment are felt both regionally and nationally, and as such, it becomes necessary to also identify the spatially impacted region.

4.2.1 The Dro-Shu Coastal Region

The Area of Influence

The Dro-Shu Coast lies between the Dro-Shu and Pa-Chang rivers, which are 25 miles apart. The entire area is almost flat, with no part rising more than 50 feet above mean sea level. The arable land area is defined by the Taiwan Channel on the west, Pa-Chang River on the north, and the Dro-Shu River on the south, and the interface of the clay strip and the pegasse (an inorganic loam-like material) on the east. This boundary is between one and five miles from the coast and encompasses a potential arable land area of 70,000 acres.

Population Distribution

The bulk of the population lives on the coastal belt, within one-half mile of the Taiwan Channel. There are two main population centers: Lu-Kang and Shian-Shi. Ribbon development has occurred along many parts of the existing coastal road, which links the village of Fu-Hsin on the south and Shen-Kang on the north. There are some 40 minor settlements which act as foci for the recreational and commercial activities along the road. The 1985 population is estimated at 35,000 persons.

Economic Activities

The prime economic activity in the region is the growing and processing of rice. In 1985, an estimated 29,000 tons of rice were shipped to the Rice Marketing Board in Chang-Hwa City. At an average price of \$190 per ton, the base component for the gross

regional product was estimated on the order of \$5,551,000. Rice is processed at 33 mills on the coast. The central mill at Shian-Shi is government owned, while the others are privately owned. The 1985 acreage under cultivation is 30,000 acres.

Other crops are grown for either local consumption or for sale to the Chang-Hwa Marketing Corporation. Other crops cultivated include coconuts (40 acres); citrus (300 acres); plantains (150 acres); ground provisions (450 acres); bananas (300 acres); green vegetables (80 acres); and fruits (480 acres).

Drainage and Irrigation

The area is drained by minor rivers and an extensive drainage and irrigation scheme called the Ho-May scheme. A pumping station at Ho-May lifts water from the Ho-May River, a tributary of the Pa-Chang, and feeds it into Lake Ho-May. This lake acts as a reservoir for the region and is capable of irrigation 30,000 acres adequately (given that annual rainfall pattern is maintained).

Transportation

On the coast itself, road is the only means of travel between the communities from Fu-Hsin to Shen-Kang. The road serves as a vital link for all local traffic, and connects all terminals for alternative modes of access.

The coastal road or main truck road is approximately 40 miles long, out of which 16 miles can be considered paved, and the remainder "poor to all weather road." There are 110 miles of dirt farm roads that serve the current 30,000 acres of rice cultivation. During the wet seasons, these roads become impassable and seriously affect the rice production

and productivity level. Table 4.6 provides the basic socio-economic data for the Dro-Shu coast.

Table 4.6 Basic Data of the Dro-Shu Coast (Da, 1993)

<u>Basic Data</u>	
Population*	30,000 - 35,000 (1985), 30,000 - 35,000 (1995)**
Per Capita Income	2,750 (1985)
<u>Agriculture</u>	
Total Arable Land Area	70,000 Acres
Cultivated Area (Acres)	30,000 (1985), 33,000 (1990), 35,000 (1995)**
<u>Road</u>	
Collector and Farm Roads (Miles)	150 (1985), 175 (1990), 200 (1995)**
Road Expenditure (\$)	600,000 (1985), 1,250,000 (1990), 1,500,000 (1995)**

* Population for rural area usually given in ranges because of difficulty to account for everyone in poorly accessible regions.

** Projected for 1995.

Model Economic Growth Potentials

No significant industrial development is foreseen to occur I the Dro-Shu coast. The one economic area where more rapid growth might be expected to occur is in agriculture. The potential arable land area of the region is estimated at 70,000 acres, out of which only 30,000 are presently cultivated. Rice cultivation is expected to continue as the dominant economic activity of the region, and its growth is dependent on the physical limitations of the road infrastructure and the drainage and irrigation supply of the Ho-May irrigation scheme. Figure 4.2 shows a map of the Dro-Shu coast delineating the arable land area, cultivated land area, and the current transport infrastructure.

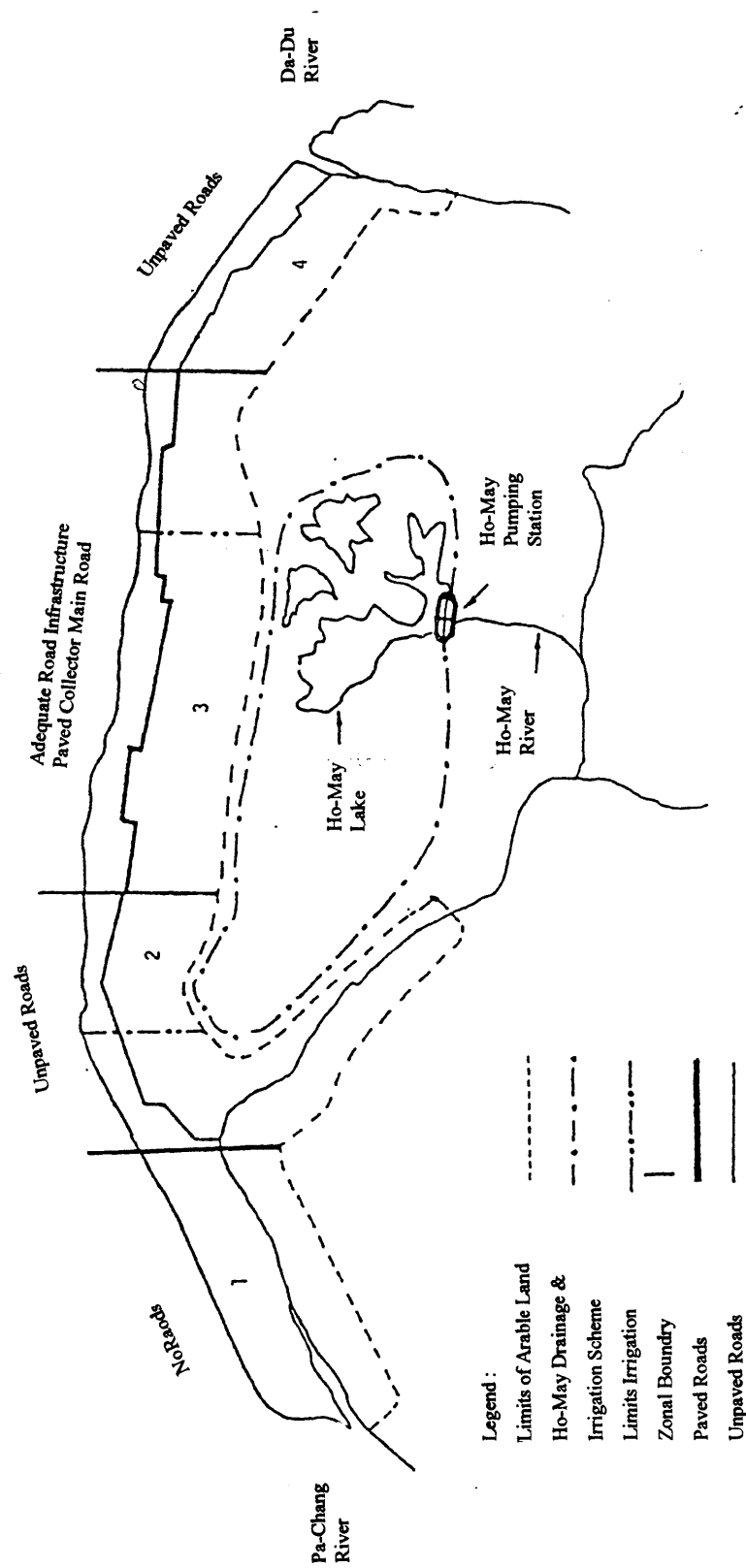


Figure 4.2 Map of Dro-Shu Coast Showing Limits of Arable Land Area, Roads, Drainage and Irrigation Infrastructure

4.2.2 The Urban or Spatially Impacted Region (Chang-Hwa City)

Chang-Hwa City's central role in regard to social and economic activities was alluded to in earlier sections. (About 95% of the total annual production and over 90% of the total population are located within a twenty or so miles of Chang-Hwa City. Over 50% of the population are located within 12.5 miles).

There are substantial flows of commodity to and from Chang-Hwa City. Those of sugar and rice from the mills to Chang-Hwa City and from Chang-Hwa City to both local and domestic markets were referred to earlier (see Table 4.2 in Section 4.1.6). Also, there are substantial daily flows of persons to and from Chang-Hwa City, including workers, traders, shoppers, clients, businesspersons, civil servants, professionals and others. Additionally, there are smaller, but lightly significant, flows caused by less frequent long-distance trips. It appears that the bulk of the county's total daily person trips occurs within the metropolitan area and that almost all of the county's long-distance trips -- both domestic and local -- either originate in, pass through, or terminate in Chang-Hwa City.

Chang-Hwa City is Chang-Hwa County's hub. It holds a commanding position in regard to Chang-Hwa County's social and economic activities. It holds a parallel position in regard to the total person and goods flow. It is Chang-Hwa County's political and cultural center, and will undoubtedly remain in the main center of activities and flows in the future. Decisions taken in any region will affect Chang-Hwa City and its future socio-economic activities.

For the purpose of this study, the urban or spatially impacted region is defined as the region that extends approximately 12.5 miles from the center of Chang-Hwa City

along the Taiwan Channel and Pa-Chang River. This region accounts for more than 50 percent of the total population and production of the county (see Table 4.4). In order to provide a specific advice on the spatial impact due to in-migration to this region, it was considered necessary to subdivide the region into more representative homogeneous zones. This subdivision allows for providing explicit advice on population, jobs, housing, and highway need for the zones for the planning period. The region is subdivided into four zones, as shown in Figure 4.3. Zone 1 -- Chang-Hwa City -- is the defined geographic capital of Chang-Hwa County, consisting primarily of government services, shopping centers, port facilities and light industries. Zone 2 -- North Bank -- is predominantly sugar cultivation, internal shipping and some light industries. Zones 3 -- West Coast -- is predominantly sugar cultivation. Zone 4 -- South Pa-Chang -- is predominantly rice and sugar cultivation. Table 4.7 provides the basic socioeconomic data for the four zones of the urban region.

Table 4.7 Basic Data of Urban Region (Da, 1993)

<u>Basic Data</u>		Zone 1 Chang-Hwa City	Zone 2 North Bank	Zone 3 West Coast	Zone 4 South Pa-Chang
<u>Population*</u>	1985	199,800	36,600	78,250	82,250
	1995	235,700	54,600	122,000	104,200
	2005	281,050	112,200	180,700	134,850
<u>Jobs</u>	1985	54,400	9,000	9,054	134,850
	1995	77,930	15,870	12,250	26,970
	2005	107,700	27,900	17,400	36,250
<u>Land Area (Acres)</u>		5,000	48,000	70,000	70,000

* Value for 1995 and 2005 are projected values.

4.3 The System Dynamic Model's Levels, Main Assumptions, and Equations

The behavior of a system is the outcome of the feedback loops that underly the structure of the system. Feedback loops govern action and change in the system from the simplest to the most complex. A feedback loop is the closed path that connects an action to its effects on the surrounding conditions, and these resulting conditions in turn come back as “information” to influence further action (Forrester, 1961). Two kinds of variables dominate a feedback loop -- level and rates. Levels are the accumulation (integration) and describe the state or condition of a system at any point in time. Rates are flows that cause the level to change and are generally associated with policies or decision-making in the system.

In order to understand the behavior of a large complex socio-economic system, it is often necessary to first understand the behavior of components (or main variables, or small sub-system) of the system and then link the components or subsystems to form a “representative” model of the system. Table 4.8 shows the breakdown of the proposed Rural Transportation Planning Model (RURTRAN) in terms of (1) the regions represented; (2) the sectors of regions; (3) the main components or levels that underly the structure and determine the behavior of the region; and (4) the concepts or hypothesized phenomenon represented by the main components or levels.

Figure 4.3 shows a simplified block diagram of the linkage of the main socio-economic sectors and implied shift in population within the study region (i.e., the model's boundary). Investments in the economic infrastructure (i.e., roads and/or drainage and irrigation) in the rural region (Dro-Shu Coast) affect regional income per capita and

unemployment. Furthermore, the perceived differences of these indicators to those of the urban region would result in shifts in population in either direction, as depicted by the double-headed arrow. It should be noted that the urban region in Figure 4.3 is divided into zones, as previously discussed. The major characteristics of each zone relative to those of the county's capitol are also shown in this figure.

Table 4.8 Rural Transportation Planning Model (RURTRAN):
Hierarchical Order of Structure

Regions	Sectors	Levels (Main Components)	Concepts
Rural – Dro-Shu Coast (Directly Impacted Through Investments)	Demographic	Population	Growth depends on births, death, migration, and influences unemployment and housing.
		Housing	Growth depends on population and consumes land area.
		Rice Land Cultivated	Level ultimately depends on available arable land acreage; and determines production and jobs.
	Agricultural	Farmers	Farmers availability determines cultivation level.
		Drainage and Harvesters	Impacts of mechanization on cultivation intensity and yields.
Rural – Dro-Shu Coast (Directly Impacted)	Agricultural	Tractors and Harvesters	Impacts of mechanization and cultivation intensity.
		Agricultural Technicians	Influence of farmers education on cultivation intensity and farm productivity.
		Road Miles	Impacts of accessibility on land development rate.
	Transport	Trucks and After Production Loss	Impacts of transport capacity on amount of after production loss.
		Road Fund	Financial constraint on road construction and maintenance.
Urban Region – (Spatially Impacted Through Population Movements)	Demographic	Population	Similar as above; also the concept of distribution to the various urban zones.
		Housing	Similar as above; but growth constrained by land availability.
	Economic	Businesses, Services, and Manufactures	Impacts jobs, unemployment rate and land.

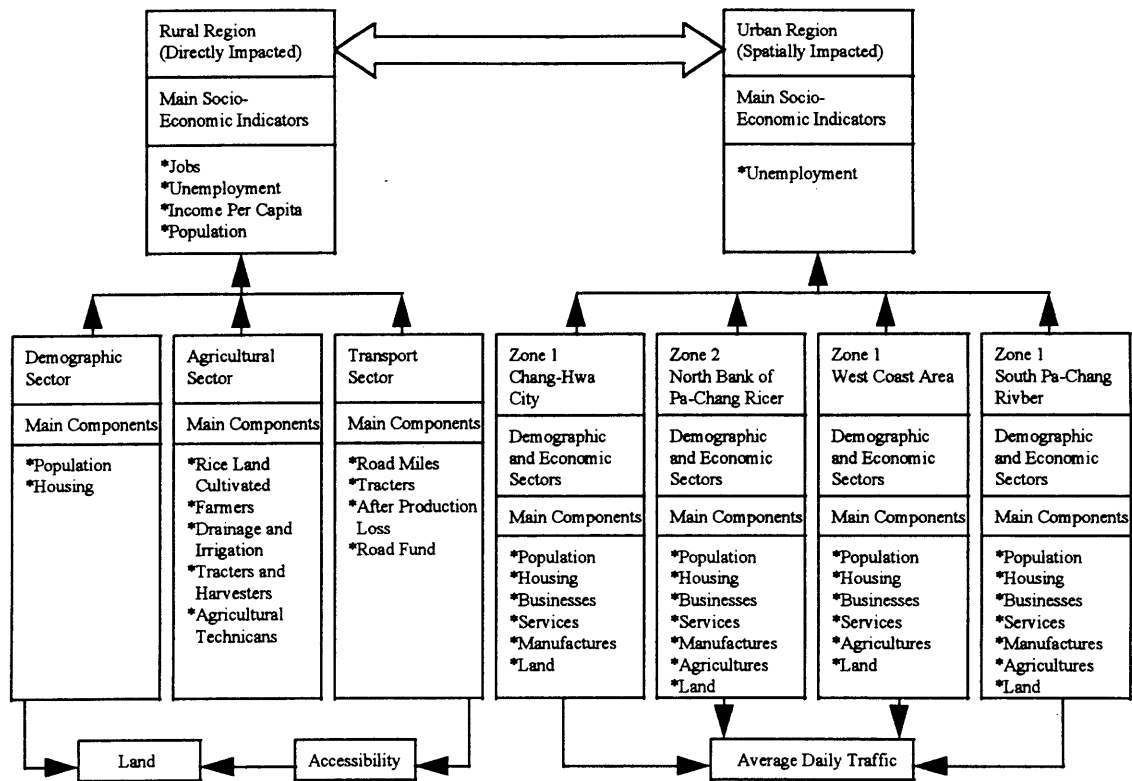


Figure 4.3 Simplified Block Diagram Showing Sectoral Linkages and Interdependence

From these main relationships, twelve levels have been chosen to develop the rural region (i.e., the investment region), and five levels to represent the urban region (i.e., the spatially impacted region). The development of the comprehensive model through the phases of assumptions and/or hypotheses, feedback loops, and mathematical equations is next presented in this section.

4.3.1 The Rural Region (Directly Impacted): Demographic Sector

The objective of the development is to change the socio-economic characteristics of this region through investments in the economic infrastructure (for example, in transportation and/or drainage and irrigation). The region is represented by three sectors --

demographic, agricultural, and transportation -- that dynamically interact with each other to produce the region's behavior through time.

The demographic sector of the model is designed to project the level of population, the supply of labor force, and the housing stock of the region. The trace of these demographic variables through time provides information on unemployment and housing needs of the region.

The Population Level

In most transportation planning model, regional population forecasts have been based mainly on extrapolation of trends or on available forecasts that were adopted for the study. The negative feedback loop in Figure 4.4 exploits the use of causal forces to determine the regional population level.

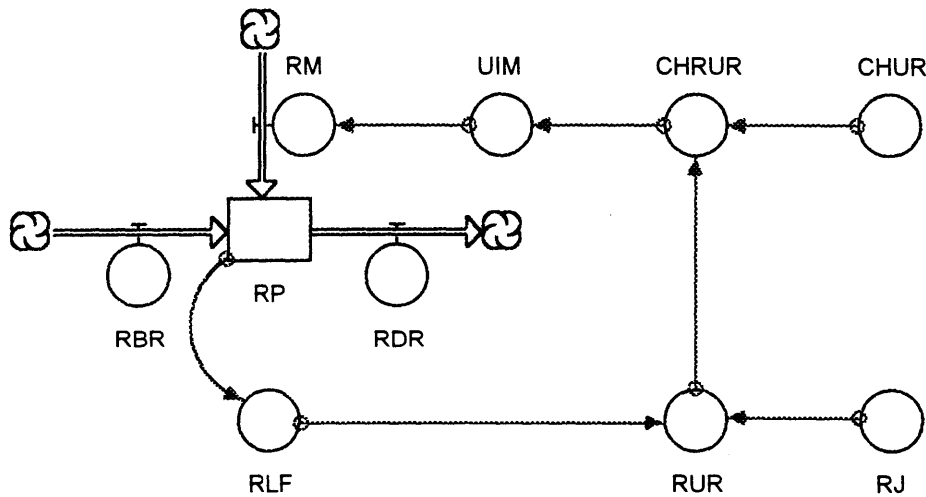


Figure 4.4 Population Level and Assumptions

The population at any point in time is dependent on births, deaths, and migrations. However, because of the causality and feedback phenomenon hypothesized in Figure 4.4,

the forecast of the regional population level is significantly different from values that would be obtained by the traditional extrapolative methodologies, since this approach treats population and employment as an interacting process. These interactions, between population and employment of the impacted regions, are an important part of the dynamics of regional economics and shifts in population, as explained below.

Births and deaths may be relatively easily obtained and moreover dependable over a planning period. Migration, however, has the greatest potential for fluctuation, especially in the short run. In this study, migration is assumed to depend strongly on the job opportunities between the rural and urban regions, as expressed by the Chang-Hwa-to-Rural-Unemployment Ratio (CHRUR).

The impacts of the relative unemployment on migration is shown in Figure 4.5, in which a hypothesized linear relationship for a given direction of flow between regional unemployment ratio and inter-regional migration is used. The graph is based on the premise that given equal unemployment rates, there will be very little shift to the urban region (achieved thorough the Urban In-Migration Multiplier, UIM); otherwise, there would be as much as a negative four percentage of shifts if the ratio is doubled; and a positive four percentages if the ratio is halved)i.e., implying a greater propensity for urban in-migration). No known study has been conducted in Chang-Hwa to justify a linear relationship; however, studies (Hen, 1988, and Lieu, 1992) conducted for the county government of Chang-Hwa have found a linear relationship using job opportunities as the independent variable.

Equations 1 through 4 define rural population RP, rural birth RBR, rural death RDR, and rural migration RM, respectively.

L	$RP = RP + (DT)(RBR - RDR - RM)$	1.0
N	$RP = 35000$	1.1
R	$RBR = RP * RBRN$	2.0
C	$RBRN = 0.028$	2.1
R	$RDR = RP * RDRN$	3.0
C	$RDRN = 0.006$	3.1
R	$RM = RP * UIM$	4.0

where,

RP	: Rural Population (People)
RBR	: Rural Birth Rate (People/Year)
RBRN	: Rural Birth Rate Normal (People/Year)
RDR	: Rural Death Rate (People/Year)
RDRN	: Rural Death Rate Normal (People/Year)
RM	: Rural Migration Rate (People/Year)
UIM	: Urban In-Migration Multiplier (Dimensionless)

Urban In-Migration Multiplier, UIM, is an attractiveness multiplier which responds to changes in the job opportunities existing in the two regions (i.e., urban and rural) and is defined in Equation 5 as a GRAPH function. Since the graph cannot contain all possible values of a finite number of points, and the computer assumes that the graph is a straight line between points -- as shown in Figure 4.5.

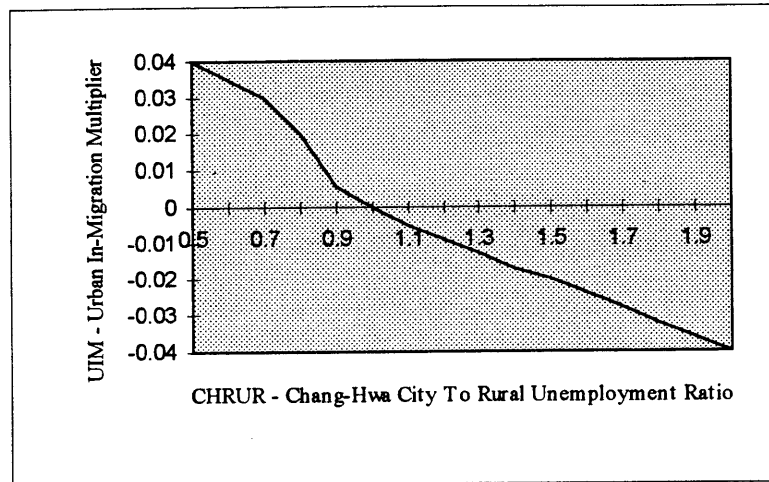


Figure 4.5 Urban In-Migration Multiplier

A UIM = GRAPH (CHRUR) 5.0

(0.5, 0.04), (0.6, 0.035), (0.7, 0.03), (0.8, 0.02),
 (0.9, 0.005), (1.0, 0), (1.1, -0.005), (1.2, -0.009),
 (1.3, -0.013), (1.4, -0.017), (1.5, -0.02), (1.6, -0.024),
 (1.7, -0.028), (1.8, -0.032), (1.9, -0.036), (2.0, -0.04)

where:

UIM : Urban In-Migration Multiplier (Dimensionless Coefficient)

CHRUR: Ratio of Chang-Hwa City Unemployment Rate to Rural

Unemployment Rate

The Housing Level

Very rarely, if ever, the housing variable is explicitly dealt with in transportation planning for a rural region, since it may be argued that in sparsely populated regions housing nor land is a constraint to development. This, however, is only a short-term characteristic of the rural scenario. Housing, in its proper perspective, must be viewed as a

variable that consumes the prime economic asset of the rural region (i.e., arable land), and in the long-run does influence the cultivation level of the region through the land fraction used for housing the rural population. Figure 4.6 shows the causal and feedback phenomenon between the demand for and supply of rural housing. The variables involved are Rural Housing, Rural Households to Houses Ratio, Rural Housing Construction Multiplier, and Rural Housing Construction Rate. These variables form a negative feedback loop which indicates that housing construction is strongly influenced by the housing construction multiplier, which is dependent on the demand for housing relative to its supply, as expressed by the ratio of rural households to the number of houses in the region. Furthermore, the housing stock positively impacts the rural land occupancy.

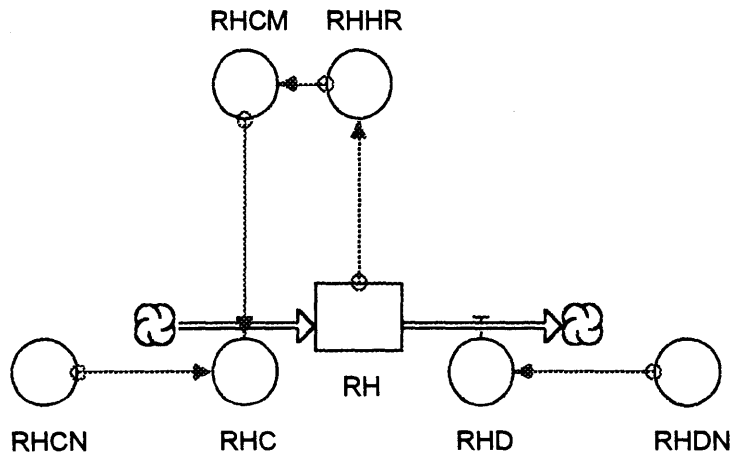


Figure 4.6 The Housing Level and Assumptions

The housing stock, RAH, as shown in Equation 6, is dependent on housing construction rate, RHC, and housing deterioration rate, RHD.

$$L \quad RAH = RAH + (DT)(RHC - RHD) \quad 6.0$$

$$N \quad RAH = 3000 \quad 6.1$$

where:

RAH : Rural Houses (Housing Units)

RHC : Rural Housing Construction (Housing Units/Year)

RHD : Rural Housing Deterioration (Housing UNITS/Year)

The Rural Housing Construction Multiplier, RHCM, shown in Figure 4.7, modulates the Rate of Housing Construction, RHC, in response to the demand for housing, as defined by the variable Rural Households to Houses Ratio, RHHR. Figure 4.7 shows the assumed response of this multiplier to demand. The assumption is that given adequate housing, i.e., a ratio of 1, construction will proceed at some normal rate, and the multiplier increases or decreases depending on the demand relative to the supply.

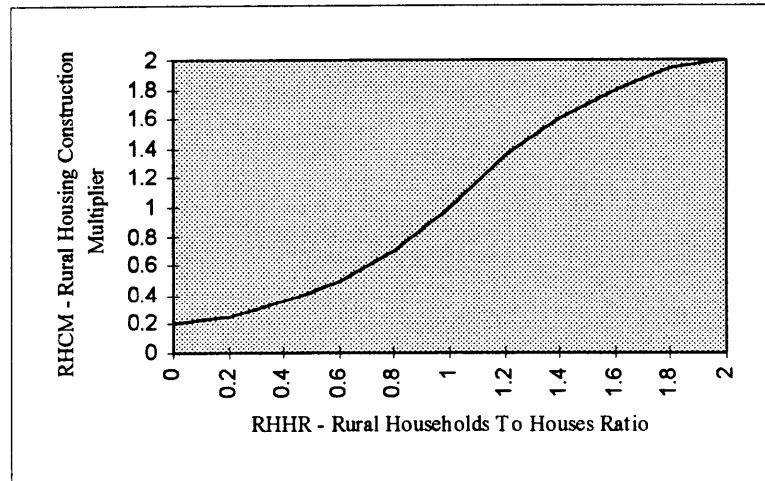


Figure 4.7 Rural Housing Construction Multiplier

The Housing Construction Rate Multiplier is expressed in a graph function as follows:

$$A \quad RHCM = \text{GRAPH}(RHHR) \quad 7.0$$

$$(0, 0.2), (0.2, 0.25), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7), (1, 1),$$

(1.2, 1.35), (1.4, 1.6), (1.6, 1.8), (1.8, 1.95), (2, 2)

where:

RHCM: Rural Housing Construction Multiplier (Dimensionless)

RHHR : Rural Households-To-Houses Ratio (Fraction)

4.3.2 The Rural Region: Agricultural Sector

The economy of the region is determined by the growth of the rice industry. The cultivation level of the rice industry determines the number of jobs provided and the Gross Region Income Per Capita. Furthermore, cultivation and production of the sector depend on the following main components (variables): (1)farmers, (2) arable land area, (3) drainage and irrigation, (4) tractors and harvesters (mechanization), (5) agricultural techniques (agricultural technique inputs), and (6) transportation (as hypothesized and presented in Table 4.8). The causality and feedback phenomena of the sector's main components were illustrated in Figure 3.4, Chapter 3.

Rice Cultivation

Figure 4.8 shows the interdependence and feedback phenomena of the main variables that determine the regional cultivation level. Rice land cultivated RL (Equation 8) is a system level which represents the acreage of land cultivated at any point in time and is calculated as the acreage at the preceding point in time, plus the acreage that has been added by the rice land development rate RLDR, in the intervening interval, minus the acreage that has been converted to other uses by the rice land conversion rate. The initial level of cultivation is 30,000 (Equation 8.1).

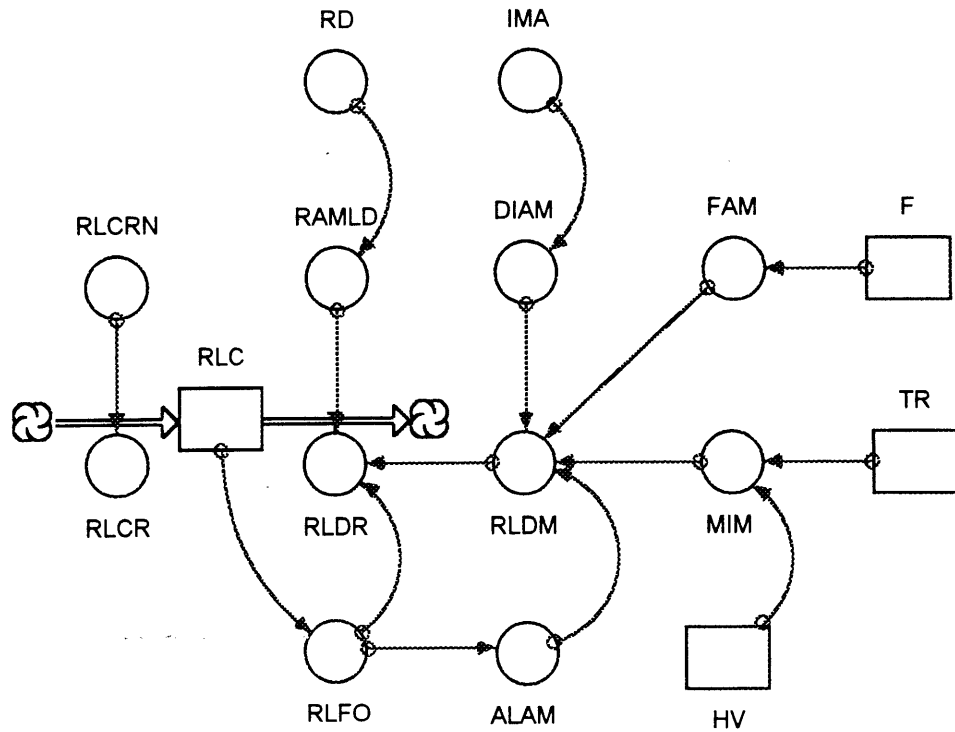


Figure 4.8 The Interrelationships of the Variables that Influence Land Development Rate and Cultivation

$$L \quad RL = RL + (DT)(RLDR - RLCR) \quad 8.0$$

$$N \quad RL = 30000 \quad 8.1$$

where:

RL : Rice Land Cultivated (acres)

RLDR : Rice Land development (acres/year)

RLCR : Rice Land Conversion Rate (acres/year)

The rice land development rate is part of the negative feedback loop (Figure 4.8). the land development rate depends on the resources of the region, i.e., economic infrastructure (road and drainage and irrigation); natural resources (viable arable land); mechanization (tractors and harvesters); and people (farmers). The impacts of the

availability of these resources are introduced into the mathematical formulation as “multipliers” that modify the normal or expected growth rate during any intervening interval. Under favorable conditions (i.e., more than adequate provision of resources), the multiplier increases; and under adverse conditions (i.e., lack of resources), the multiplier decrease.

The rice land development rate (Equation 9) in any intervening future interval is the maximum of the difference of the fraction of the rural land area made accessible by the road network, as defined by the road accessibility multiplier on land development rate RAMLD, the rural land fraction occupied, RLFO, at the present time, and zero. Furthermore, the area or acreage that is finally developed depend on the cumulative impacts of the available resources, as defined by the rice land development multiplier RLDM and the time required to bring virgin land under cultivation, as defined by delay in land development DILD. Thus, explicitly including the fact that road alone does not expand farming:

$$R \quad RLDR = \frac{\text{MAX} (RLDR * RLA * (RAMLD - RLFO), 0) * 9.0}{(DILD)}$$

where:

RLDR : Rice Land Development Rate (acres/year)

MAX : A Maximum Function Which Prevents Negative Values

RLDM : Rice Land Development Multiplier (a Dimensionless variable; is the product of the following multipliers: land availability ALAM, farmer availability FAM, drainage and irrigation availability

DIAM, mechanization MIM, and profit from farming PRFM)

RLA : Rural Land Area (acres)

RLFO : Rural Land Fraction Occupied (fraction)

DILD : Delay In Land Development (years)

RAMLD: Road Accessibility Multiplier (the proportion of the rural land area that is made accessible by the road network)

Agricultural Land Availability Multiplier ALAM, an auxiliary variable, reflects the impacts of the stage at which the region is being farmed on land development rate. Figure 4.9 graphs the values of the multiplier versus the land fraction occupied. The assumption is that the rate at which new land is developed depends on the present stage of cultivation. At zero occupancy, the multiplier is 1, and growth is dependent on other factors listed in Equation 9. At full occupancy, the multiplier is 0, and the limit to cultivation is reached irrespective of other inputs to the region. Equation 10 quantifies the assumed impact of land availability on land development rate.

$$\begin{aligned} \text{A} \quad \text{ALAM} &= \text{GRAPH}(\text{RLFO}) && 10.0 \\ & (0, 1), (0.1, 1.2), (0.2, 1.3), (0.3, 1.4), (0.4, 1.5), \\ & (0.5, 1.4), (0.6, 1.3), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25), \\ & (1, 0) \end{aligned}$$

where:

ALAM: Agricultural Land Availability Multiplier (Dimensionless)

FLFO : Rural Land Fraction Occupied (fraction)

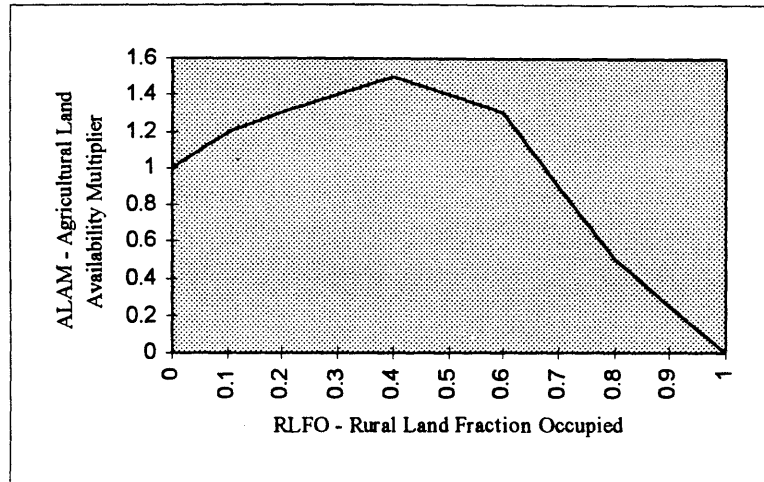


Figure 4.9 Agricultural Land Availability Multiplier

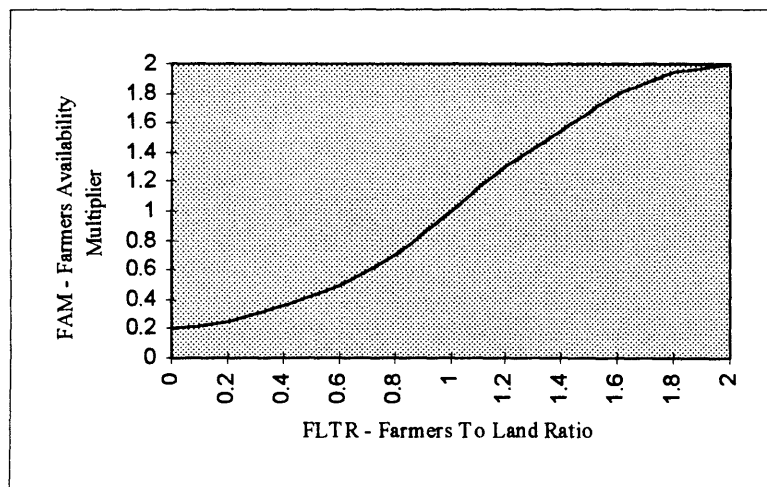


Figure 4.10 Farmers Availability Multiplier

Farmers Availability Multiplier FAM (Equation 11) quantifies the assumed impacts of framers availability on the rice land development rate. The assumption is that a surplus of framers (as measured by the ratio of framers to rice land) positively influences the rate at which new land is brought under cultivation. Figure 4.10 shows the values of the multiplier versus the ratio of framers to rice land cultivated.

A $FAM = GRAPH(FLTR)$

11.0

(0, 0.2), (0.2, 0.25), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7),
 (1, 1), (1.2, 1.3), (1.4, 1.55), (1.6, 1.8), (1.8, 1.95), (2, 2)

where:

FAM : Framers Availability Multiplier (dimensionless)

FTLR : Framers To Rice Land Ratio (fraction)

Drainage and Irrigation Multiplier DIAM, second to accessibility, is probably the most important infrastructure to both land development rate and yield per acre. The water availability is measured by the rice land to water ratio. As this ratio increases, land development rate reduces (i.e., as the system of drainage and irrigation becomes inadequate for the area under cultivation, framers reduce their rate of cultivation). The influence of available drainage and irrigation on land development rate is shown through the drainage and irrigation multiplier. The unwillingness of framers to expand cultivation under inadequate drainage and irrigation condition is quantitatively expressed in Equation 12 and graphically shown in Figure 4.11. It is assumed that if rice land to water ratio is greater than 1.0, land development rate becomes dependent on the regional rainfall characteristics for water supply. In this case, the drainage and irrigation multiplier, DIAM, assumes a constant value of 1.6 (the lowest value in the graph).

$$A \quad DIAM = \text{GRAPH}(\text{RLTWR}) \quad 12.0$$

(0, 2), (0.2, 1.95), (0.4, 1.9), (0.6, 1.85), (0.8, 1.75),
 (1.0, 1.6), (1.2, 1.6), (1.4, 1.6), (1.6, 1.6), (1.8, 1.6),
 (2.0, 1.6)

where:

DIAM : Drainage and Irrigation Multiplier (dimensionless)

RLTWR: Rice Land To Water Ratio (fraction)

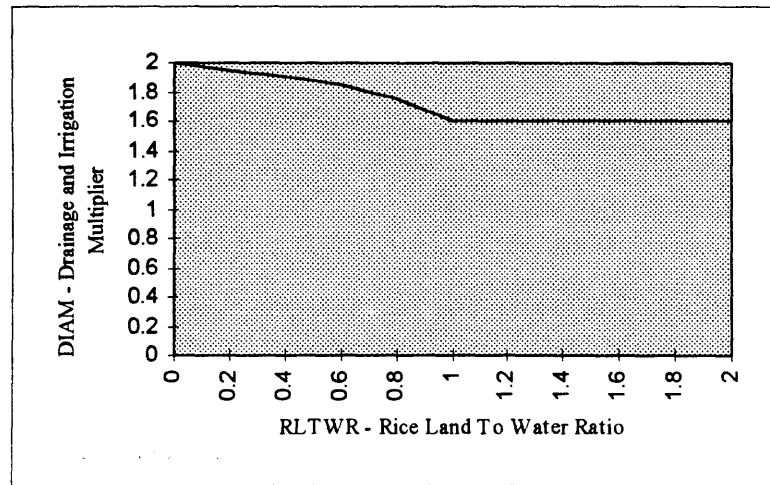


Figure 4.11 Drainage and Irrigation Multiplier

Mechanization Multiplier MIM - Ordinarily, land development rate would be restricted by the capability of the individual framers to the cultivation of a certain acreage through labor intensive means. However, mechanization has greatly enhanced the individual framer's capabilities to undertake increased cultivation. The mechanization multiplier is defined as the product of two multipliers, tractor availability multiplier and harvester availability multiplier, as shown in Equation 13. The cultural practices of rice framing are such that these two equipment play unique roles in the phases of rice framing - tractors in the sowing phase, and harvesters in the reaping phase -- and can independently influence output levels. Figures 4.12 and 4.13 and Equations 14 and 15 indicate the quantitative impacts of the availability of this equipment on land development rate.

$$A \quad MIM = RLHRM * RLTRM$$

13.0

A RLHRM = GRAPH (RLTHR) 14.0

(0, 1), (0.2, 1), (0.4, 1), (0.6, 1), (0.8, 1), (1, 1), (1.2, 0.95),
(1.4, 0.9), (1.6, 0.5)

A RLTRM = GRAPH (RLTR) 15.0

(0, 1.3), (0.2, 1.2), (0.4, 1.1), (0.6, 1), (0.8, 1), (1, 1),
(1.2, 0.95), (1.4, 0.8), (1.6, 0.6)

where:

MIM : Mechanization Multiplier (dimensionless)

RLHRM: Rice Land To Harvester Multiplier (dimensionless)

RLTRM: Rice Land To Tractor Multiplier (dimensionless)

RLTR : Rice to Tractor Ratio (fraction)

RLTHR: Rice Land To Harvester Ratio (fraction)

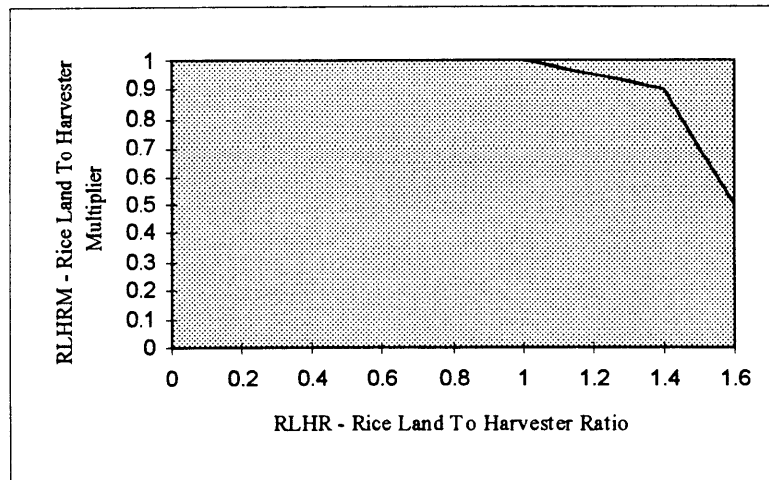


Figure 4.12 RLHRM - Rice Land To Harvester Multiplier

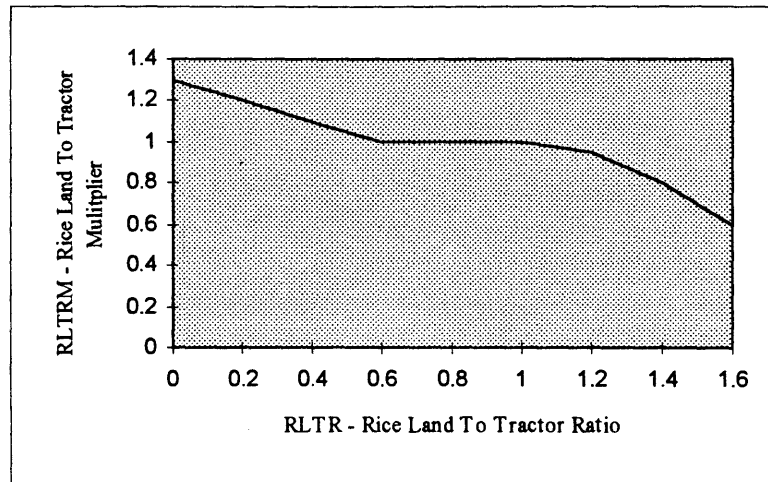


Figure 4.13 RLTRM - Rice Land To Tractor Multiplier

Rice Production and Productivity

Production and productivity determine regional income per capita. Figure 4.14 shows the variables that determine the production rate of the region. The production rate during any interval of time is determined by Equation 16, which is simply the product of the acreage cultivated RL, and the average yield per acre YPA.

$$R \quad UMRPR = RL * YPA \quad 16.0$$

where:

UMRPR: Unmilled Rice Production (tons/crop)

RL : Rice Land Cultivated (acres)

YPA : Average Yield Per Acre (tons/acre)

Figure 4.14 shows that yield per acre (or productivity) depends on four major inputs: (1) drainage and irrigation DIAM, (2) mechanization MIM, (3) fertilizer FEAM, and (4) framers technical input HM. The concepts of drainage and irrigation and mechanization have already been discussed. the variable FEAM (fertilizer input multiplier)

will be discussed in the transport sector, since its use is directly dependent on the cost of transportation within the study region.

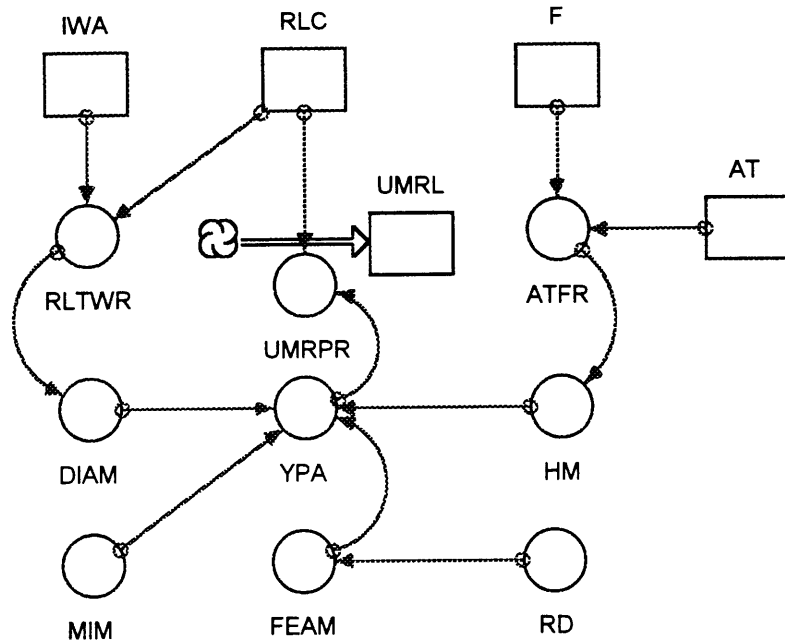


Figure 4.14 The Interrelationships of the Variables That Influence Production and Productivity

Equation 17 defines the value of yield per acre as follows:

$$A \quad YPA = YPAN * FEAM * DIAM * MIM * HM \quad 17.0$$

where:

YPA : Average Yield Per Acre (tons/acre)

YPAN : Normal Yield Per Acre (tons/acre)

FEAM : Fertilizer Availability Multiplier (dimensionless)

DIAM : Drainage and Irrigation Multiplier (dimensionless)

MIM : Mechanization Multiplier (dimensionless)

HM : Husbandry Multiplier (dimensionless)

Equation 17 quantifies the impacts of the availability of each of the above key resources as a multiplier value. It says that the average normal yield per acre YPAN (a situation where the farmer is operating without assured drainage, irrigation, mechanization, fertilizer and technical advice) will increase, depending on the inputs of the above resources.

The Husbandry Multiplier HM, represents the influence of agricultural extensions services in the region as a function of the ratio of the number of trained agricultural technicians to the number of farmers in the region. The assumption here is that as the number of trained personnel increases, the technical input into farming is also increased. Figure 4.15 and Equation 18 show the assumed impact of trained personnel in the region on impact.

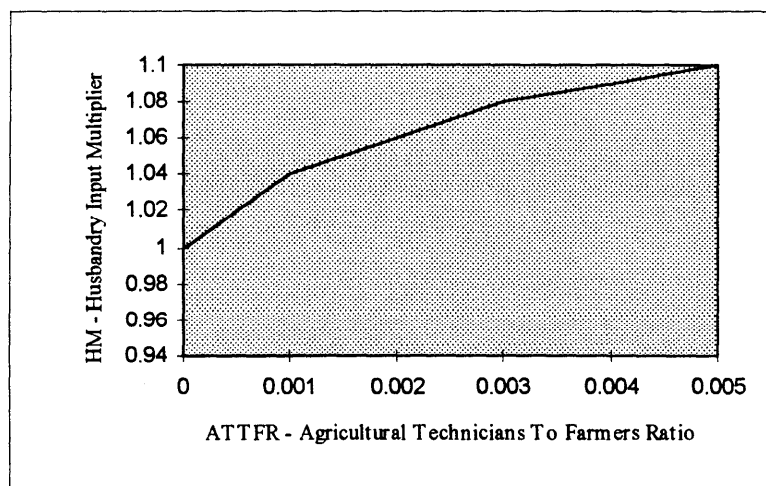


Figure 4.15 HM - Husbandry Input Multiplier

$$A \quad HM = \text{GRAPH}(\text{ATTFR}) \quad 18.0$$

$$(0, 1), (0.001, 1.04), (0.002, 1.05), (0.003, 1.08),$$

$$(0.004, 1.09), (0.005, 1.1)$$

where:

HM : Husbandry Multiplier (dimensionless)

ATTFR: Agricultural Technicians To Framers Ratio (fraction)

4.3.3 The Rural Region: Transportation Sector

The transport sector, which is the primary focus of the model's design, is presented by modes, road and rail, with the dominant emphasis on road investment. In this scenario, road accessibility is perceived to be the primary constraint to land development rate; and rail transportation is incorporated such that the desired rail transport capacity keeps pace with the regional production level projected from improved road accessibility. The road transport sector is explicitly represented by three levels -- Road Fund RF, Rural Road Miles RROAD, and Trucks TRUCK -- that dynamically interact to produce the inter-sector behavior.

Relationships between Road Fund and Rural Road Miles

The concept of the demand and supply for road is shown in the negative feedback loop represented by the variables Demand for Road, Road Construction Rate, Rural Road Miles, and Road Density in Figure 4.16. The regional land area and the crop type to be cultivated determine the network mileage needed -- the demand. The road fund provided for new construction determines the road construction rate -- the supply. An increase in road construction rate increases the network mileage; and this, in turn, increases the regional road density, which negatively impacts the demand for roads. Thus, an equilibrium condition is expected when actual road density reaches the desired road density. Equations 19, and 20, given below, define the level of funding and road mileage at

any given point in time. Equation 19.1 and 20.1 give the initial fund and mileage of roads at the beginning of the simulation.

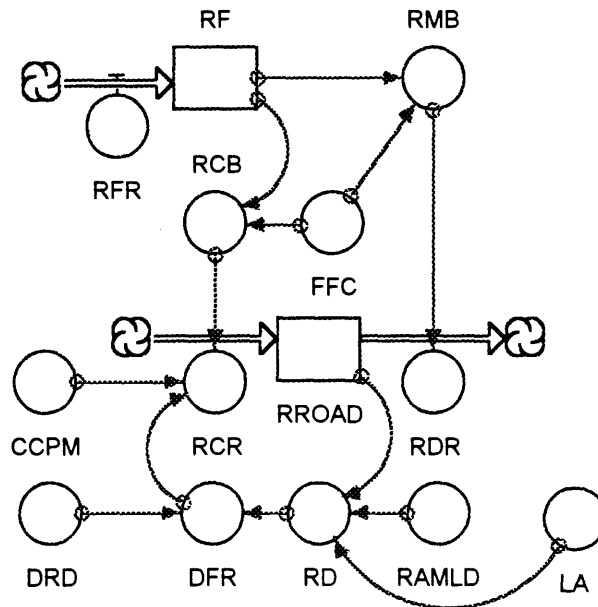


Figure 4.16 The Interrelationships Between Road Fund and Road Miles (The Demand/Supply Concept)

$$L \quad FR = RF + (DT)(RFR) \quad 19.0$$

$$N \quad RF = 1000000 \quad 19.1$$

$$L \quad RROAD = RROAD + (DT)(RCR - RRDR) \quad 20.0$$

$$N \quad RROAD = 150 \quad 20.1$$

where:

RF : Road Fund (\$/year)

RFR : Road Funding Rate (\$/year)

RROAD: Rural Road Network (miles)

RCR : Road Construction Rate (miles/year)

RRDR : Rural Road Deterioration Rates (miles/year)

The amount of road to be provided or the desired road density is determined by the crop type to be cultivated, since different crop types required different agricultural infrastructure for full access and drainage and irrigation (dirt roads or dams). In this scenario, the cultivation of rice is best served by the layout shown in Figure 4.17. This layout requires approximately five and one-half miles of road infrastructure with the following characteristics: 0.5 mile of paved collector; 2.5 miles of all-weather sealed road; and 2.5 miles of dirt road to serve approximately 1,000 acres of rice and costs approximately \$550,000 for initial construction and approximately \$17,500 to maintain per year.

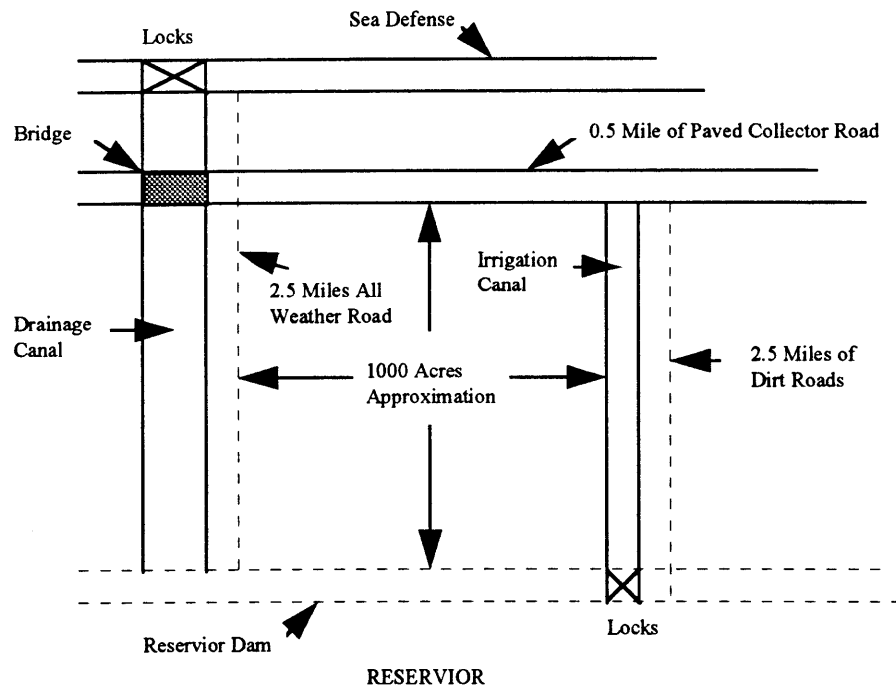


Figure 4.17 Typical Layout Rice Farm Roads and Drainage and Irrigation Infrastructure

Impacts of Rural Road Miles on Accessibility and Transport Capacity

The concepts of road accessibility on land development rate and unmilled rice loss or after-production loss are illustrated in Figure 4.18. An increase in rural roads increases the road density, and an increased road density increases the road accessibility multiplier RAMLD, which positively impacts the rice land development rate and therefore rice land under cultivation.

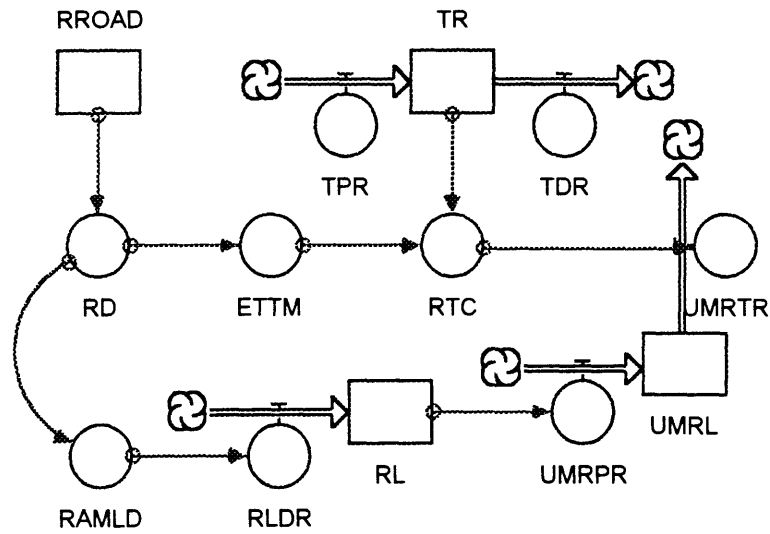


Figure 4.18 The Concept of Accessibility and Transport Capacity on Production Loss

The road accessibility multiplier, RAMLD, an auxiliary variable, reflects the impacts of rural road density on land development rate. Lack of accessibility by road is often stated as the prime cause for the slow rate of rural development; but equally important is that road expansion per se should not be mistaken for a complete development. The assumed relationship between road density and accessibility is showed in Figure 4.19. In this figure, the assumption is made that at a zero road density (i.e., no roads), rice land development rate is due to factor as defined in Equation 9 for rice land

development rate; while at the desired road density, the entire region is assumed to be accessible for cultivation. Equation 21 quantifies the assumed impact of the road accessibility multiplier.

$$A \quad \text{RAMLD} = \text{GRAPH} (\text{ARD}/\text{DRD}) \quad 21.0$$

$$(0, 0.1), (0.1, 0.2), (0.2, 0.4), (0.3, 0.5), (0.4, 0.55),$$

$$(0.5, 0.6), (0.6, 0.65), (0.7, 0.7), (0.8, 0.8), (0.9, 0.9), (1, 1)$$

where:

RAMLD: Road Accessibility Multiplier (dimensionless)

ARD : Actual Road Density (fraction)

DRD : Desired Road Density (fraction)

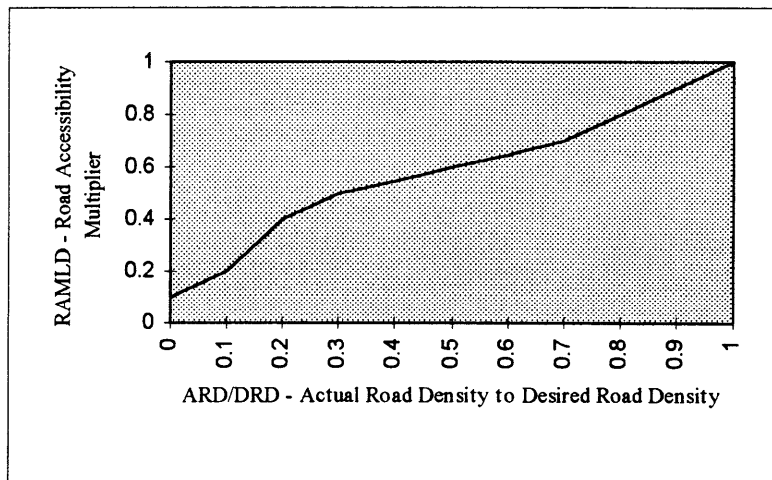


Figure 4.19 Road Accessibility Multiplier

Unmilled rice loss, UMRL, or after-production loss, is the loss that farmers suffer from not being able to transport their produce immediately to the mills due to inadequate transportation capacity. The nature of paddy (i.e., unmilled rice) is such that after reaping, if it is not moved to storage and/or drying locations within a short period of time, the

grains are damaged. These damages result in lower prices for the farmers. Thus, the after-production loss is not a physical loss of tonnage -- since the farmers eventually transport their crops to the mill -- but a significant financial loss may be incurred to farmers due to inadequate transport capacity. The concept illustrated in Figure 4.24 is the minimization of after production loss by providing matching road transport capacity for the projected rice production rate. Equation 22 quantifies the after-production loss (i.e., unmilled rice loss) as the difference between the unmilled rice production rate and the unmilled rice transport rate as follows:

$$L \quad UMRL = UMRL + (DT)(UMRPR - UMRTR) \quad 22.0$$

where:

UMRL : Unmilled Rice Loss (tons/crop)

UMRPR: Unmilled Rice Production Rate (tons/ crop)

UMRTR: Unmilled Rice Transport Rate (tons/crop)

Road Transport Capacity, RTC, 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 of time over which rice production must be harvested and transported. The road transport capacity is defined in the model as:

$$A \quad RTC = TRUCK * TTPD * HPP * PLPT \quad 23.0$$

where:

RTC : Road Transport Capacity (tons/crop)

TRUCK: Number of Trucks in the Industry (number)

TTPD : Truck Trips Per day (average no. of trips/truck/day)

HPP : Harvesting Peak Period (days)

PLPT : Pay Load Per Truck (tons/truck)

Impacts of Rural Road Miles on Rice Land Cultivated and Yield

Improved accessibility generally means reduced transport cost, which should be reflected in increased farming inputs -- especially fertilizer and husbandry input. Figure 4.20 illustrates the impacts of improved accessibility through the negative feedback loop defined by Rural Road Miles, Road Density, Actual Road Density Cost Multiplier, Farming Cost of Transport, Fertilizer Inputs, Fertilizer Availability Multiplier, Yield Per Acre, Profit Per Acre, Rice Land development Rate, Rice Land Cultivated, Unmilled Rice Production Rate, Truck Trips, and Road Deterioration. The loop shows that improved accessibility, defined by the Road Density variable, reduces the actual road density multiplier, which in turn, reduces the transportation cost. A reduction in transport cost, FCOT, means an increase in fertilizer input, FI, leading to higher yield per acre, YPA. Increased yield means increased production rate, which results in more truck trips and increased road deterioration. The loop implies that road maintenance after construction is equally important if sustained stable agricultural production is to be realized.

The availability of fertilizer, implied by the fertilizer availability multiplier, FEAM, is a function of fertilizer inputs per acre. Increased fertilizer inputs cause yield per acre to increase. Figure 4.21 shows the values of the multiplier for different levels of inputs of fertilizer. The multiplier increases at a decreasing rate, suggesting that after a certain point, additional fertilizer may not be as economical.

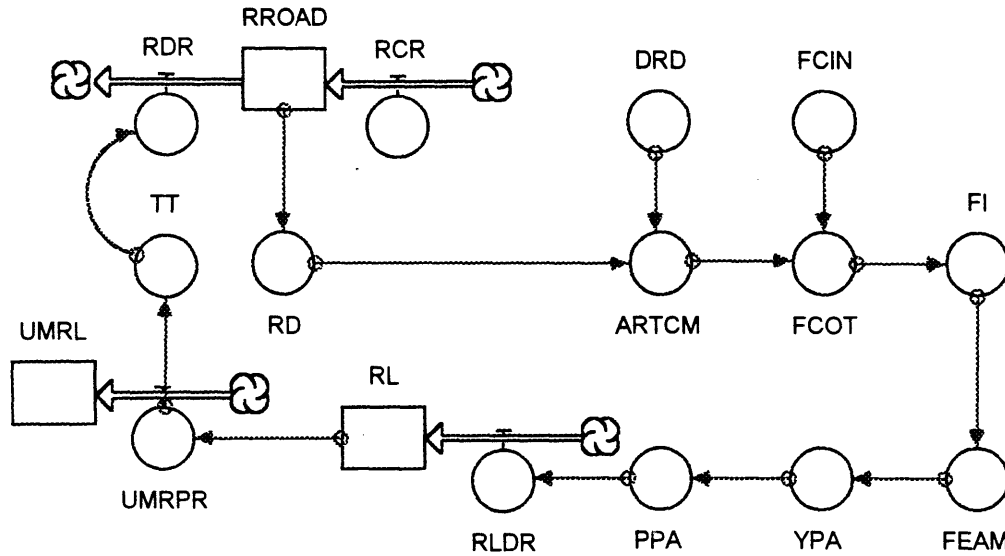


Figure 4.20 The Concept of Improved Access on Fertilizer Inputs Production Rate and Road Deterioration

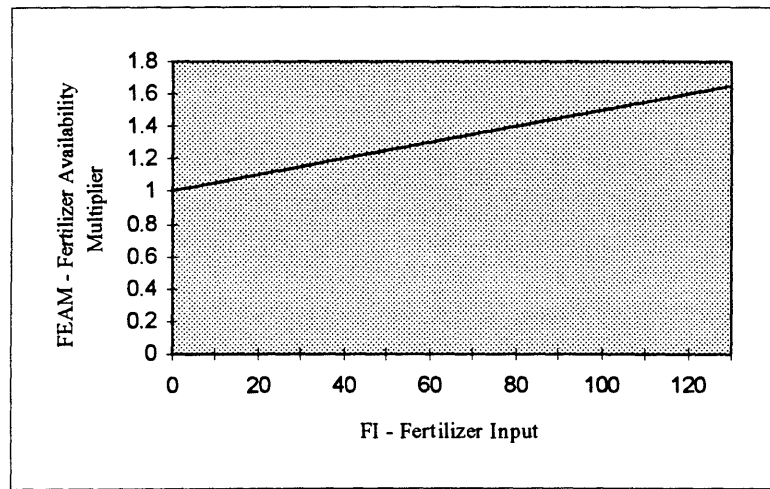


Figure 4.21 FEAM - Fertilizer Availability Multiplier

The Actual Road Density Cost Multiplier, ARTCM, reflects the impact of increasing road density on the farming cost of transportation. As actual road density to the desired road density increases, the multiplier drops, causing a corresponding drop in transportation cost. Figure 4.22 shows the assumed behavior of the multiplier. At zero

road access, transport costs are assumed to be one and one-half times higher than that of a region with 70% actual to desired road density.

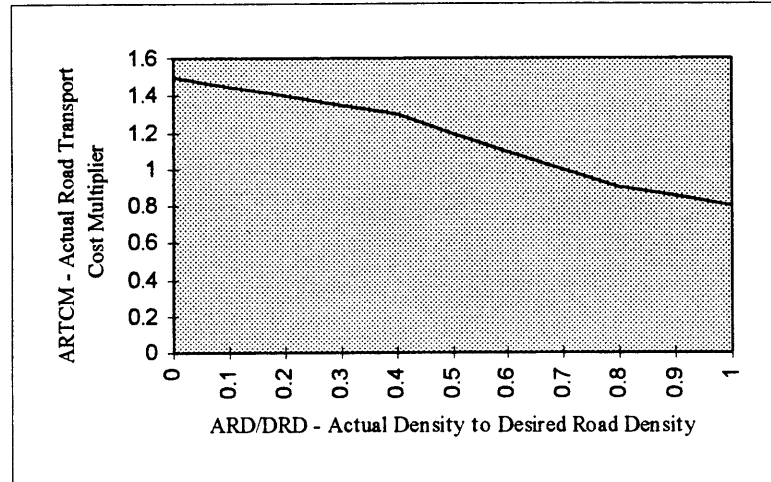


Figure 4.22 ARTCM - Actual Road Transport Cost Multiplier

4.3.4 The Urban Region (Spatially Impacted Region)

The development of a model for the immediate region of influence of the investment would have sufficed in most rural transportation planning approaches; however, an attempt is made here to explicitly incorporate any spatial impacts due to investments in rural region. In Section 4.2.2, the spatially impacted region has been identified as the county capital Chang-Hwa City, and a distance of approximately 12.5 miles along the Taiwan Channel and the Banks of the Pa-Chang River. Furthermore, this region was divided into four semi-homogeneous zones in order to provide more explicit understanding of the impacts on the region through zonal behavior. The levels and assumptions of a typical zone are presented; the remainder of the formulation is presented in Appendix 1.1 as part of the comprehensive system dynamics model. Zone 1 -- Chang-Hwa City -- is represented by four levels: population, housing, service structures, and

business structures. The dynamic interactions between the levels, their feedback structure and mathematical relationships are presented and discussed in this section.

Population

Figure 4.23 shows that the underlying structure of the feedback phenomenon of the zonal population level is similar to the structure of the rural population; and the discussion presented in Section 4.3.1 applies here. However, one significant difference in the urban region is the concept of the distribution of the urban immigrants. Equation 24 defines the values of the zonal population at any point in time.

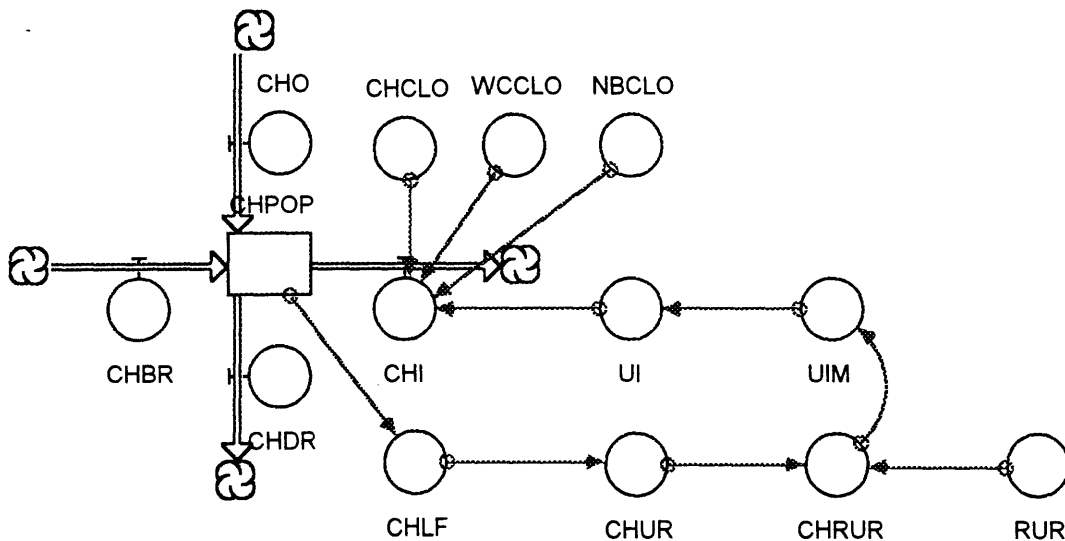


Figure 4.23 Chang-Hwa City Population Level and Assumptions

$$L \quad CHPOP = CHPOP + (DT)(CHBR - CHI - CHDR - CHO) \quad 24.0$$

$$N \quad CHPOP = 237100 \quad 24.1$$

where:

CHPOP: Chang-Hwa City Population (people)

CHBR : Chang-Hwa City Birth Rate (people/year)

- CHI : Chang-Hwa City In-Migration (people/year)
- CHO : Chang-Hwa City Out-Migration (people/year)
- CHDR : Chang-Hwa City Death Rate (people/year)

Chang-Hwa City In-Migration, CHI, as shown in Equation 25, is expressed as a function of the available civic land area of zones 1, 2, 3. The concept here is that jobs, first of all, motivated the shift of population from the rural to the urban region; but people will go to where they can find a place to live and travel to work in the urban region. Furthermore, it is assumed that the distribution of the population is based on the population of vacant land in the zones identified with housing land available.

$$R \quad CHI = (UI * (1-CHCLO)) / \quad 25.0$$

$$((1-CHCLO) + (1-WCCLO) + (1-NBCLO))$$

where:

- CHI : Chang-Hwa City In-Migration (people/year)
- CHCLO: Chang-Hwa City Civil Land Fraction Occupied (fraction)
- WCCLO: West Coast Civil Land Fraction Occupied (fraction)
- NBCLO: North Bank Civil Land Fraction Occupied (fraction)

From Equation 25, the incoming population is distributed only over three zones, while the urban region is divided into four zones. This is because time series data base has indicated that zone 4 (South Pa-Chang Rive) is not an attraction for population, which may be due to the fact that it is not directly connected by road to Chang-Hwa City, and also it is relatively more agricultural in its economic potentials (that is, its future expansion is in agricultural rather than light industries and social infrastructure).

Housing

Figure 4.24 shows the housing level is again similar to the rural housing feedback loop of Section 4.3.1, with one notable exception; that is, urban housing (zonal housing) is also affected by rural land availability (zonal land area).

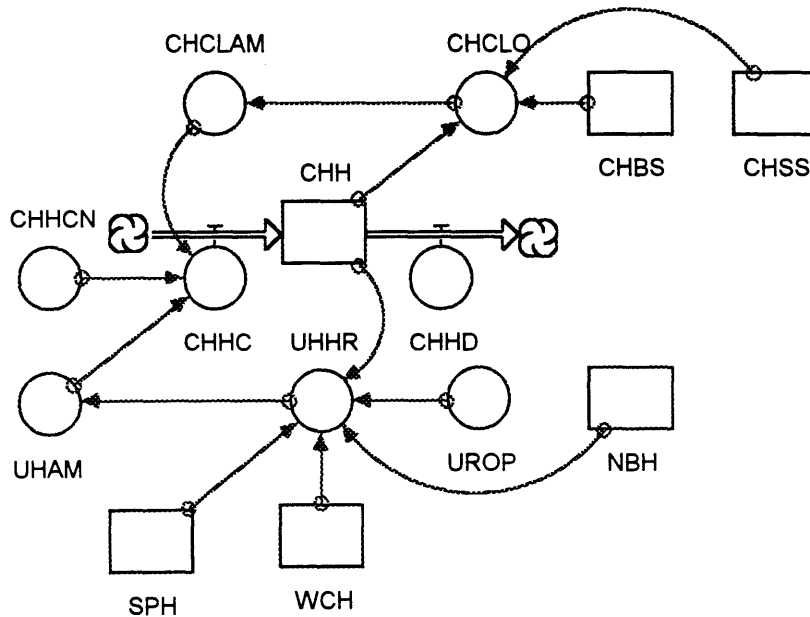


Figure 4.24 Chang-Hwa City Housing Level and Assumptions

Equation 26 defines the level of Chang-Hwa City houses at any point in time as follows:

$$L \quad CHH = CHH + (DT)(CHHC - CHHDR) \quad 26.0$$

$$N \quad CHH = 22780 \quad 26.1$$

$$R \quad CHHC = CHH * CHHCN * UHAM * CHCLAM \quad 27.0$$

$$R \quad CHHDR = CHH * CHHDRN \quad 28.0$$

where:

CHH : Chang-Hwa City Houses (units of houses)

CHHC : Chang-Hwa City Housing Construction Rate (houses/year)

CHHDR : Chang-Hwa City Deterioration Rate (houses/year)

CHHCN : Chang-Hwa City Construction Normal (houses/year)

CHHDRN : Chang-Hwa City Deterioration Normal (houses/year)

UHAM : Urban Housing Availability Multiplier (dimensionless)

CHCLAM : Chang-Hwa City Land Availability Multiplier (dimensionless)

Equation 29 defines the civic land availability multiplier CHCLAM, an auxiliary variable that reflects the influence of available housing land on the housing construction rate. In the urban scenario, land availability is probably the most important factor affecting the growth rate of urban housing. Figure 4.25 graphs the assumed values of the multiplier versus the land fraction occupied. The assumption is that a zero land occupancy construction takes place at some normal rate. However, as the land occupancy increases, construction rate increases significantly, reflecting the pattern that is normally experienced in the housing development of a region. Then, this rate drops significantly as the fraction of land occupied becomes increasingly larger.

$$\begin{aligned} \text{A} \quad \text{CHCLAM} &= \text{GRAPH}(\text{CHCLO}) && 29.0 \\ & (0, 1), (0.1, 1.15), (0.2, 1.3), (0.3, 1.4), (0.4, 1.5), \\ & (0.5, 1.4), (0.6, 1.3), (0.7, 0.9), (0.8, 0.75), (0.9, 0.5), (0, 0) \end{aligned}$$

where:

CHCALM : Chang-Hwa City Land Availability Multiplier (dimensionless)

CHCLO : Chang-Hwa City Civil Land Fraction Occupied (fraction)

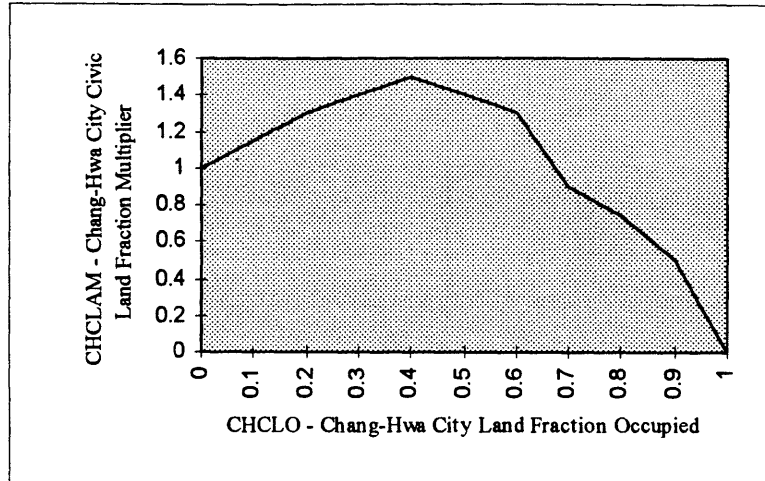


Figure 4.25 CHCLAM - Chang-Hwa City Civic Land Fraction Multiplier

Business Structures

The economy of the urban region is determined by the growth of its socio-economic activities of the zones that comprise the urban boundary. The economic activities of the zones vary -- for the Chang-Hwa City zone, Zone 1, the activities that determine the job level and consumes (or occupy) zonal land area are: (1) businesses, (2) services and (3) manufactures.

In order to incorporate these activities in a quantitative model to determine future job level and area occupied, the zonal activities were divided into three main classes given above. A representative structure was identified for each main class, and this representative structure generated a certain number of jobs and occupied a certain area of land. Given this aggregation for each class of economic activity, the causality and feedback phenomenon of each level was developed.

Figure 4.26 shows that the business structure is influenced by two main feedback loops. Loop 1 (Chang-Hwa Business Structures, Chang-Hwa City Civic Land Fraction

Occupied, Chang-Hwa City Civic Land Fraction Multiplier, Chang-Hwa City Business Structures Construction Rate) shows the impact of land availability on business structure growth rate. An increase in business structures increases the zonal land area occupied, and in turn reduces the rate of expansion of the business sector, due to reduction in available land for expansion. Loop 2 (Chang-Hwa City Business Structures, Chang-Hwa City Jobs, Urban Labor Force To Job Ratio, Urban Labor Force Multiplier, Chang-Hwa City Business Structures Construction Rate) shows the impact of labor availability on business expansion. An increase in business increases the job available, and this in turn reduces the available labor force. A reduction in the labor force slows down the expansion of the business sector.

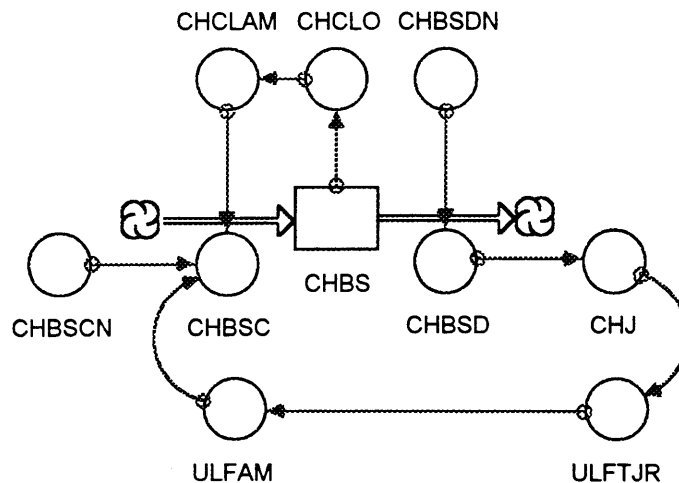


Figure 4.26 Chang-Hwa City Business Structures Level and Assumptions

Equation 30 defines the level of business structures at any point in time.

$$L \quad CHBS = CHBS + (DT)(CHBSC - CHBSD) \quad 30.0$$

$$N \quad CHBS = 72 \quad 30.1$$

where:

CHBS : Chang-Hwa City Business Structures (no. of business structures)

CHBSC : Chang-Hwa City Business Structures Construction Rate
(business structures/ year)

CHBSD : Chang-Hwa City Business Structures Deterioration Rate
(business structures/ year)

Urban Labor Force Availability Multiplier, ULFAM, as shown in Equation 31, defines the impact of labor availability in the urban region on the rate of growth of the business construction. Figure 4.27 graphs the behavior of the multiplier versus the regional unemployment characteristics, as defined by the Urban Labor Force To Jobs Ratio, ULFTJR. The assumption being an excess of labor (i.e., high unemployment), it positively impacts the rate of construction; and the opposite is true in a time of high employment.

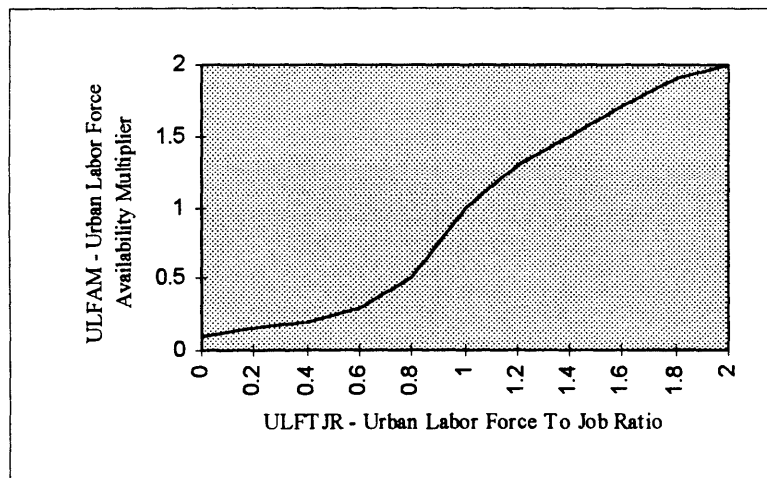


Figure 4.27 ULFAM - Urban Labor Force Availability Multiplier

Service Structures

Figure 4.28 shows the underlying structure and hypotheses of this variable (level). The structure is similar to the Chang-Hwa City Business Structure level, and the preceding explanation with respect to the multipliers ULFAM and CHCLAM applies. Equation 32 defines the value of the Chang-Hwa City Service Structures at a given point in time.

$$L \quad CHSS = CHSS + (DT)(CHSSC - CHSSD) \quad 32.0$$

$$N \quad CHSS = 725 \quad 32.1$$

where:

CHSS : Chang-Hwa City Service Structures (units of service structures)

CHSSC : Chang-Hwa City Service Structures Construction Rate
(service structures/year)

CHSSD : Chang-Hwa City Service Structures Deterioration Rate
(service structures/year)

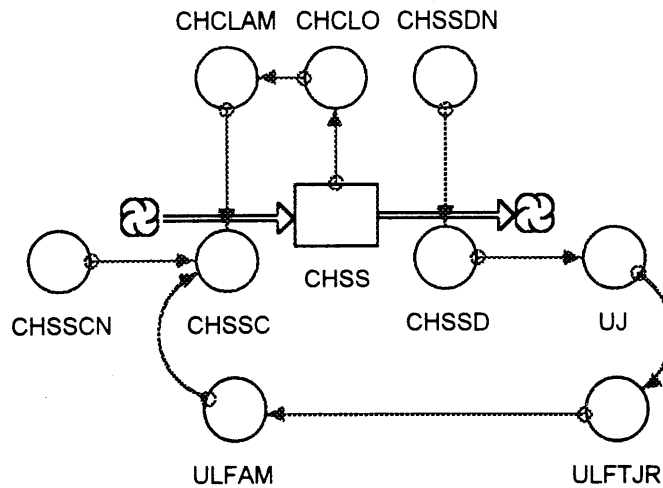


Figure 4.28 Chang-Hwa City Service Structures Level and Assumptions

Manufacturing Structures

Figure 4.29 shows the underlying structure and feedback loop for this level. The structure is similar to the service and business structures level. Equation 33 defines the value of the manufactures level at any point in time .

$$L \quad CHMS = CHMS + (DT)(CHMS - CHMSD) \quad 33.0$$

$$N \quad CHMS = 21 \quad 33.1$$

where:

CHMS : Chang-Hwa City Manufacturing Structures (no. of manufactures)

CHMSC : Chang-Hwa City Manufacturing Structures Construction Rate
(manufactures/year)

CHMSD : Chang-Hwa City Manufacturing Structures Deterioration Rate
(manufactures/year)

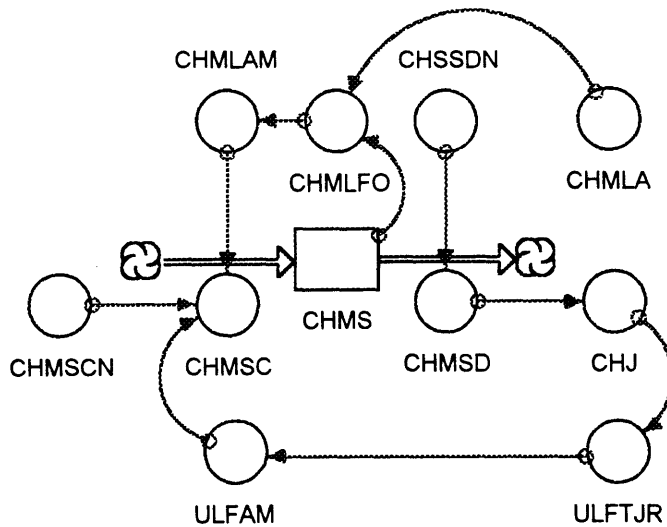


Figure 4.29 Chang-Hwa City Manufactures Level and Assumptions

4.3.5 The Comprehensive Model

The structure of the comprehensive model -- developed from the main components discussed so far -- is shown in a simplified form in Figure 4.30. The single hatched variables -- Rural Unemployment Rate RUR, Rural Land Fraction Occupied RLFO, Rice Land development Rate RLDR, After Production Loss APL, Truck Purchase rate TPR, Vessels Purchase Rate CPR, Chang-Hwa City Civic Land Fraction Occupied CHFLO, and Urban Labor Force ULF -- are where the main inter-sectoral linkage are.

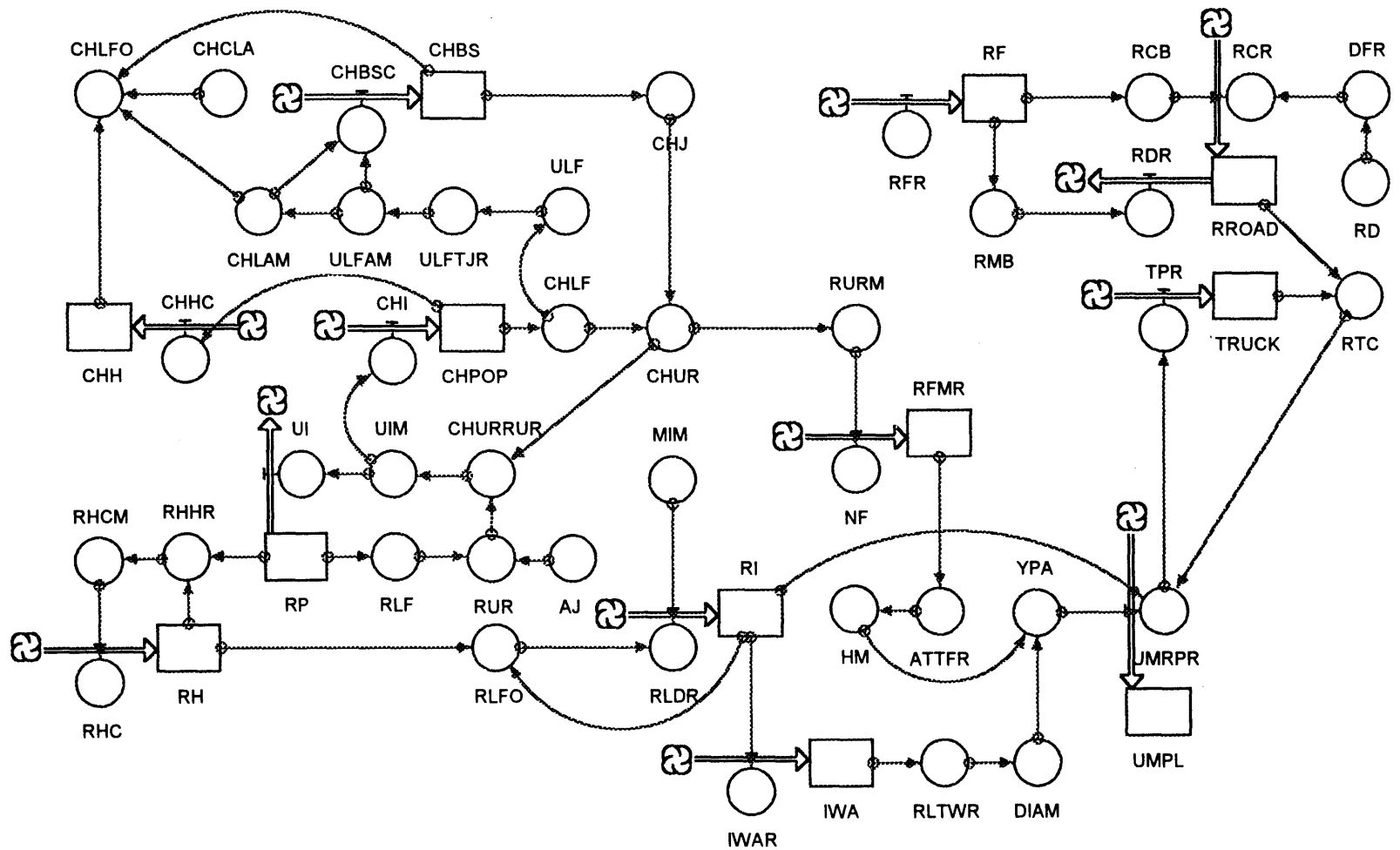
The double hatched variables -- Chang-Hwa City To Rural Unemployment Ratio CHRUR and Urban In-migration UI -- represent the inter-regional impacts; that is, a difference between the perceived job opportunities of Chang-Hwa City and the rural region results in a shift in population, depending on the perceived differences.

Appendix 1 provides the detailed documented system dynamics mathematical model, and Appendix 2 provides a key to the variable names.

Table 4.9 provides a summary of the model's main assumptions; that is, the multipliers, the influencing variables that determine the multipliers, the variables that are influenced by the multipliers, and the direction of the influence on the impacted variables.

4.4 Model Calibration

It is particularly important, with a model this large and whose formulation is based on observed data, assumptions and concepts drawn from demography, economics, agriculture, transportation, and technology, to test its predictive ability over a sample period.



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Figure 4.30 A Simplified System Dynamics Flow Diagram Showing Structure of Comprehensive Model

Table 4.9 Summary of Model Main Assumptions

Multipliers	Influencing Variables	Influenced Variables	Direction of Influences
Urban Migration - UIM -	Chang-Hwa City Unemployment Rate to Rural Unemployment Rate - CHRUR -	Rural Migration - RM -	+/-
Rural Housing - RH -	Rural Households to House Ratio - RHHR -	Rural Housing Construction - RCH -	+
Agri-Land Availability - ALAM -	Rural Land Fraction Occupied - RLFO -	Rice Land Development Rate - RLDR -	+/-
Farmers Availability - FAM -	Farmers/Land Areas Cultivated - FTLR -	Rice Land Development Rate -RLDR -	+
Drainage and Irrigation - DIAM -	Rice Land Cultivated/Water Available - RLTWR -	Rice Land Development Rate -RLDR -	-
Mechanization - MIM -	Rice Land/ Tractor - RLTRM - Rice Land/Harvester - RLHRM -	Rice Land Development rate - RLDR - Yield Per Acre - YPA -	- -
Husbandry - HM -	Agri-Technicians/Farmers -ATTFR -	Yield Per Acre - YPA -	+
Road Accessibility -RAMLD -	Actual Road Density/Desired Road Density - ARD/DRD -	Rice Land development Rate - RLDR -	+
Actual Road Density Cost - ARCM -	Actual Road Density/ Desired Road Density - ARD/DRD -	Farming Cost of Transport - FCOT -	-
Fertilizer Availability - FEAM -	Fertilizer Inputs - FI -	Yield Per Acre - YPA -	+
Chang-Hwa City Civic Land Availability - CHCLAM -	Chang-Hwa City Civic Land Fraction Occupied - CHCLO -	Chang-Hwa City Housing, Business, Service, Manufactures Structures Construction - CHHC, CHBSC, CHSSC, CHMSC -	+/-
Urban Labor Force -ULFAM -	Labor Force/Jobs - ULFTJR -	Chang-Hwa City Housing, Business, Service, Manufactures Structures Construction - CHHC, CHBSC, CHSSC, CHMSC -	+

The first step in such a calibration process is to identify a set of endogenous variables whose characteristics or behavior over the observed period more or less determine regional behavior, and whose values (i.e., available data) are dependable over the observed period.

The next step is to make several simulations or calibration runs paying special attention to the graph functions and the realism of their values over the test period, and to modify their values in an iterative manner, if necessary.

The final step is to compare the values of the predicted endogenous variables (of the model) with the actual observed values of the same variables.

The above procedure was followed for the model calibration -- for the rural region, the following variables: (1) rural population, (2) the acreage of rice land cultivated, and (3) the rural road miles, were chosen. These variables, it is felt, determine the rural overall performance (i.e., population influences the demographic sector; cultivation level influences the economic sector; while roads determines the accessibility characteristics). In the urban region -- urban population and urban jobs -- it is felt, determine the key variable of unemployment rate, which influences population movements and links the two regions.

Figures 4.31, 4.32, and 4.33 and Table 4.10 show the plots and values for the predicted (model values) and observed values for the rural region's variables.

The data base for the rural region are only estimates (i.e., these values were taken from studies that quoted them as estimates provided and developed by Council of Economic Planning and Development; especially, for the sample period among 1995 and 2005). An examination of predicted and observed values among 1995 and 2005 is to

ensure the reliability of developed model to the comprehensive socio-economic planning module developed by Council of Economic Planning and Development, Executive Yuan. Table 4.10 reveals that the model has a relatively high explanatory power over the sample period (1985 - 2005), with the model's values being very close to the observed values for the set of endogenous variables used and a reliable acceptance for goodness-of-fit test. The highest differences between predicted and observed value is 8 percent.

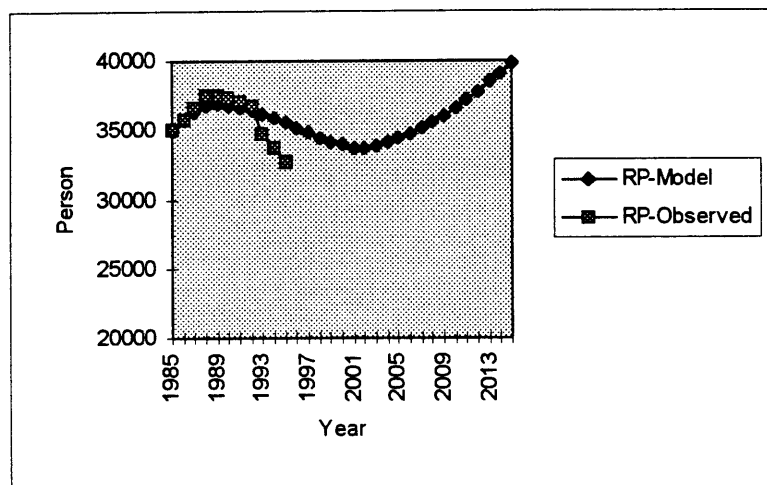


Figure 4.31 The Plots of Observed and Model Values for Rural Population

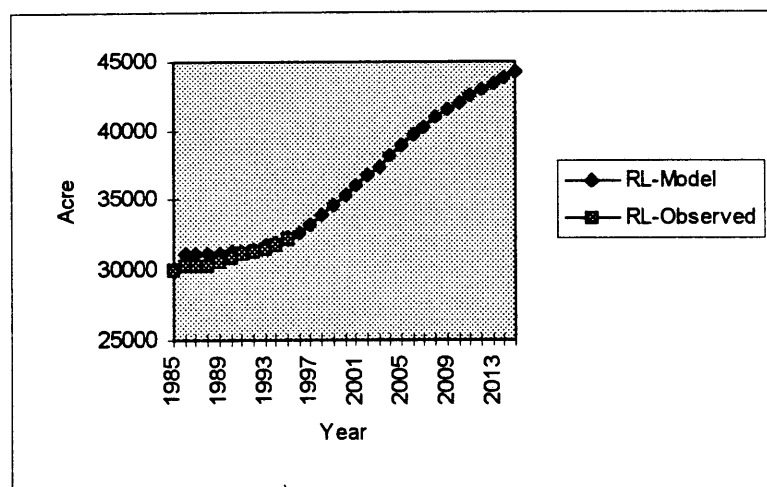


Figure 4.32 The Plots of Observed and Model Values for Agricultural Cultivation

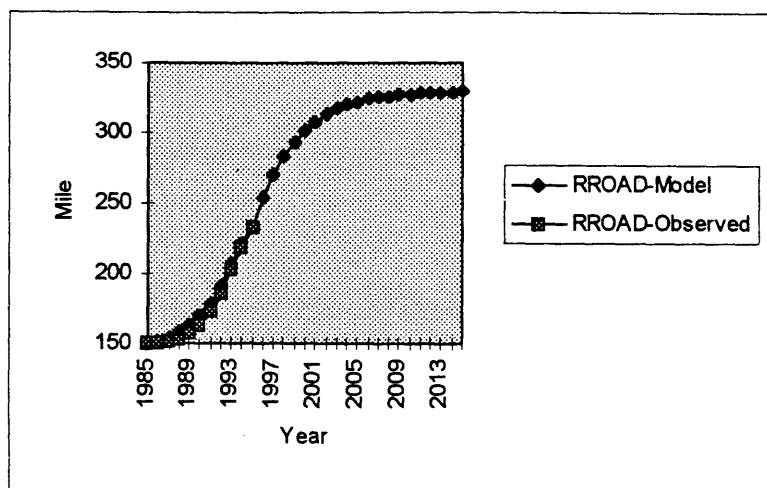


Figure 4.33 The Plots of Observed and Model Values for Rural Road Miles

Table 4.10 Predicted (Model) and Observed Values of Rural Population, Cultivations and Roads

Variables	1985	1990	1995	2005
Population (Persons)				
-Model	35,000	36,827	35,583	34,405
-Observed	35,000	37,380	32,736**	N.A.
-Percent Difference	0.00*	1.5%	8%	--
Cultivation (Acres)				
-Model	30,000	31,176	32,198	38,883
-Observed	30,000	30,864	32,037**	N.A.
-Percent Difference	0.00*	1%	<1%	--
Roads (Miles)				
-Model	150	170	233	321
-Observed	150	163	232**	N.A.
-Percent Difference	0.00*	4%	<1%	--

* Beginning of simulation.

** Forecasted values.

N.A. Not Available

Note: R-Squares for variables of population, cultivation, and roads are 0.59, 0.73, and 0.99. T-Statistics are 0.0422, 0.0041, and 0.0003 which are all within 95% of confidence interval while the T-Value of 10 degrees of freedom is 0.0784. Both statistics show reliable acceptance for goodness-of-fit test.

Table 4.11 shows the values for the urban region's variables. Table 4.11 shows population variation is between 8 and 13 percent between model and observed values, with the divergence being highest for the year 2005. These differences are not considered too large for model calibration, especially when the fact that the observed values are also forecasted values and would obviously be different from true values. Similarly, in the case of the job variable, the maximum differences occur in the year 2005 and are only the order of 9 percent, and therefore considered acceptable. While using goodness-of-fit test, values of R-Square and T-Statistics also show reliable acceptance for modeling effectiveness.

Table 4.11 Predicted (Model) and Observed Values of Urban Population and Urban Jobs

Variables	1985	1990	1995	2005
Population (Persons)				
-Model	396,900	458,317	532,233	713,035
-Observed	396,900	N.A.	489,647**	620,339**
-Percent Difference	0.00*	--	8%	13%
Jobs				
-Model	96,050	116,325	136,932	174,054
-Observed	96,050	N.A.	132,825**	158,392**
-Percent Difference	0.00*	--	3%	9%

* Beginning of simulation.

** Forecasted values adopted from Council of Economic Planning and Development (1994).

N.A. Not Available

Note: R-Squares for variables of population and jobs are 0.68, and 0.74. T-Statistics are 0.0155 and 0.0046 which are all within 95% of confidence interval. Both statistics also show reliable acceptance for goodness-of-fit test.

The listing and definition of variables of the calibration model are presented in Appendix 1.1 and 1.2. This model will be used in Chapter 5 to determine the rural investment alternative that provides the most beneficial national impacts.

Chapter 5

Analyses of Alternative Investment Strategies

If a road network is built to stimulate economic growth, then a much more satisfactory basis for estimating the benefits would seem to be one which measures the increases in production and changes in other socio-economic factors. This can be done directly without reference to traffic volume, except for the structural design of the roadway.

Likewise, it is important to recognize that the estimates of output are not based on only marginal reduction in transport costs. The development project, which embodies a variety of factors, should instead be considered as removing a bottleneck to production so that discrete rather than marginal changes to production can occur. Thus, instead of a single numerical indicator for the value of a project, a set of socioeconomic characteristics should be used in the evaluation process. It is for these reasons that the practices in highway economics offer only limited insight into the overall impacts of the investments.

In this study the traditional practices -- Benefit Costs (B/C) and Net Present Value (NPV) -- analyses will be undertaken, since for all intent and purpose, quantification in monetary terms is still the single-most desirable and utilized indicator of the impacts of the investments; but benefits for production instead of traffic flow will be evaluated for the given outlay. However, final recommendations will be based also on analyses of the behavior of the following set of socio-economic characteristics through time (i.e., the anticipated life of the investments): (1) impacts on production and productivity; (2)

impacts on population, migration, jobs, unemployment and gross regional income per capita; and (3) spatial impacts of each investment strategy.

Approaches to rural development (i.e., investment strategies) in DCs vary from a piecemeal, uncoordinated investment in roads and other infrastructure to a comprehensive, detailed, planned, funded and executed project. For convenience, this continuum of investment approaches is divided into three main alternatives: (1) Do Nothing, (2) Investments in Roads Only, and (3) Investments in Road, Drainage and Irrigation, for simulation by the calibrated model developed in Chapter 4. Section 5.1 will deal with analyses of the socio-economic impacts of the "Do Nothing" strategy; Section 5.2, the "Road Investment Only" strategy; Section 5.3 the comprehensive investment strategy of "Road, Drainage and Irrigation." In Section 5.4, the differences of the three alternatives will be discussed with specific emphasis on the spatial impacts and timing of receipts.

5.1 "Do Nothing" Alternative

In a real world scenario, nations never really completely neglect their rural regions, except for those areas which are labeled "jungle" with zero output and population. Whereas the desired level of investment is not forthcoming (in many cases because of traffic demand evaluation techniques and prioritization), cognizance is taken of the contribution of these rural regions to the national economy. In addition, funds are allocated to maintain, at least, the status quo and in some cases also to provide a minimum of funding for expansion of the economic infrastructure.

As such, the "Do Nothing" alternative is a pseudonym for the continuation of the status quo of the region (i.e., whatever has been the history of the funding and performance of the region is assumed to continue into the future).

The Dro-Shu Region falls in this category of "Do Nothing" strategy, since feasibility studies conducted between the period 1985-1988 for the Dro-Shu Region, based primarily on traffic demand concept, recommended no major investment in the region (i.e., the expansion of the road network was found to be infeasible at a five percent interest rate). However funds for the region did not totally "dry up"; and as shown in Chapter 4, Table 4.6, funding continued at an average rate of approximately one million dollars per year, with fluctuation as shown in the table. For the "Do Nothing" alternative, this strategy of funding is assumed to continue in the foreseeable future with annual increases of approximately ten percent to take care of price increases in labor, materials, etc.

Thus, from a modeling point of view, no modification is made to the calibrated model developed in Chapter 4 for the socio-economic analyses of the region. The developed model is simply "projected" or simulated for another twenty years, to the year 2015, and the analyses of the socio-economic behavior of the region over the period is considered as the "Do Nothing" alternative.

5.1.1 Economic Analysis

In this study, the general form of the economic efficiency criterion for measuring the direct consequences of the project follows the concept of "shadow prices". It says that project should be accepted whose Net Present Value is maximizing where:

$$\text{Net Present Value} = \sum_{j=0}^n [(B_j - C_j) / (1 + i)^j]$$

and,

j : the year in which benefits and costs occur

n : the period of the analysis

B_j : the value of benefits in the j year

C_j : the value of costs in the j year

i : the interest rate used for discounting, which is also the shadow price of capital (Shaner, 1966)

$(1 + i)^j$: the discounting factor required to place the benefits and costs which occur in different years on a directly comparable basis

Alternatively, the concept of a highest benefit/cost ratio is used for accepting a project -- where the ratio is simply the Net Present Value of all receipts divided by the Net Present Value of all costs for a stated period.

In this case study, annual receipts or benefits are those accruing from the sale of its agricultural produce (i.e., rice); and annual expenses are those accruing from farming and roads and/or investment on other infrastructure. These are:

$$\text{Farming Costs per Annum} = \text{RL} * \text{CFA}$$

where:

RL : Rice Land cultivated per year (acres).

CFA : Farming Cost per Acre (dollars).

and;

$$\text{Total Road Expenses per annum (RER)} = \text{RCE} + \text{RME}$$

where:

REC : Road Construction Expenses per year (dollars).

RME : Road Maintenance Expenses per year (dollars).

and;

$$\text{Receipts or Benefits per annum} = \text{UMRPR} * \text{SPT}$$

where:

UMRPR: Unmilled Rice Production Rate per year (in tons).

SPT : Selling Price of unmilled rice per Ton (in dollars, equals to \$200).

Table 5.1 The Computer printout of the Main Variables Used in the Economic Analysis

Year	RL	CFA	RROAD	RER	RCE	RME	UMRPR
1995.00	33374.33	223.36	233.47	6493695.00	5326345.00	1167350.00	57651.44
1996.00	34120.22	223.33	238.70	3716878.00	2523360.00	1193518.00	57725.20
1997.00	34878.45	223.34	251.33	2519552.50	1262890.00	1256662.50	58052.70
1998.00	35622.74	223.37	261.94	2370607.50	1060900.00	1309707.50	58510.45
1999.00	36337.55	223.41	271.39	2301353.75	944425.00	1356928.75	59310.52
2000.00	37018.18	223.45	278.80	2135871.25	741850.00	1394021.25	60403.69
2001.00	37663.37	223.48	284.94	2038218.30	613521.00	1424697.30	61454.28
2002.00	38269.86	223.52	290.75	2034373.50	580644.00	1453729.50	62458.98
2003.00	38836.77	223.55	295.59	1962603.60	484642.00	1477961.60	63408.73
2004.00	39364.63	223.58	299.99	1939898.60	439940.00	1499958.60	64298.79
2005.00	39854.85	223.61	303.80	1899626.40	380636.00	1518990.40	65127.53
2006.00	40309.38	223.63	307.30	1886290.90	349810.00	1536480.90	65895.66
2007.00	40730.44	223.66	310.37	1858947.24	307110.80	1551836.44	66605.42
2008.00	41120.34	223.68	313.11	1840199.20	274631.20	1565568.00	67260.02
2009.00	41481.40	223.69	315.57	1823941.50	246070.00	1577871.50	67863.15
2010.00	41815.85	223.71	317.85	1816778.00	227530.00	1589248.00	68418.68
2011.00	42125.82	223.72	319.93	1807622.80	207976.00	1599646.80	68930.44
2012.00	42413.28	223.73	321.77	1792401.60	183576.00	1608825.60	69402.14
2013.00	42680.08	223.74	322.99	1737398.10	122450.00	1614948.10	69837.24
2014.00	42927.90	223.75	323.89	1709849.20	90382.00	1619467.20	70238.96
2015.00	43158.73	223.75	324.08	1639098.00	18696.00	1620402.00	70609.14

Legend:

RL	: Rice Cultivated	CFA	: Cost of Farming Per Acre
RROAD	: Road Miles	RER	: Total Road Expense
RCE	: Road Construction Expense	RME	: Road Maintenance Expense
UMRPR	: Unmilled Rice Production		

The "Do Nothing" policy (Table 5.1) evaluated at ten percent (%) interest rate for the analysis period from year 1995 to 2015 results in a Net Present Value of the road expenditure of approximately \$21,605,880 and the Net Present Value of the receipts of approximately \$34,656,141. These flows result in a benefit/cost ratio of 1.62 and a Net Present Value of \$13,050,260.

5.1.2 Analyses of Other Socio-Economic Indicators

The "Do Nothing" alternative satisfies both the benefit/cost ratio and the net present benefit criteria and is therefore a potential viable candidate for recommendation. However, as earlier contended, development strategies should be based not only on a ratio greater than one nor positive cash flows, but on the overall improvement and the least negative impact to the region or nation, as measured by the main regional socio-economic indicators.

Figure 5.1 shows the computer plot for cultivation, production and road. The rice industry (acres cultivated) grows at a decreasing rate and does not reach its true potential in terms of acres cultivated until the year 2015 (Table 5.1). Cultivation follows the expansion of the road network; thus, accessibility by road is undoubtedly one of the major constraints to the expansion of the rice industry. A close examination of production rate and cultivation level (UMRPR/RL) shows that productivity (yield per acre) has remained constant at approximately one and one-half ton per acre throughout the analysis period. Thus, the "Do Nothing" alternative constrains growth and productivity in the rice industry; and as such, the expansion of the regional economy, since rice production is the mainstay of the economy of the region.

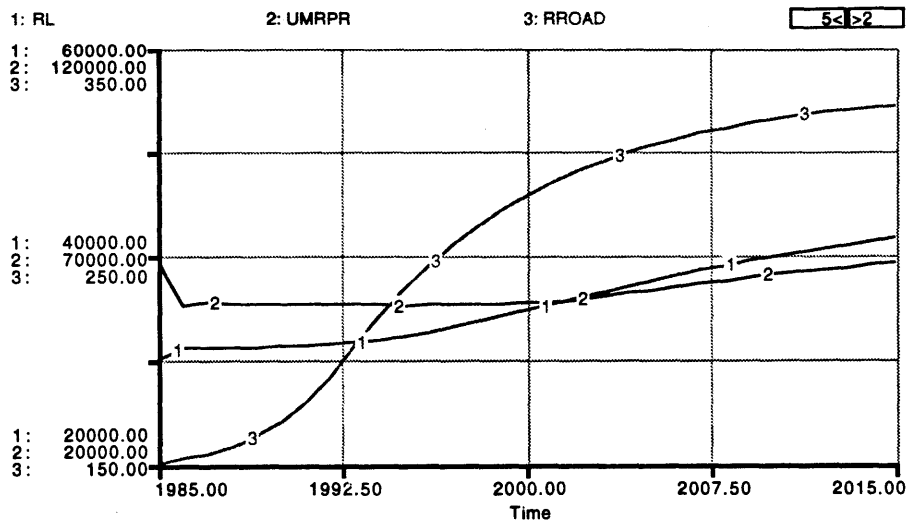


Figure 5.1 The Computer Plot of Main Economic Variables - Roads, Cultivation, and Production

5.1.2.2 Impacts on Population and Income Per Capita

Rural population is determined by birth, death and migration rates; and further, migration is determined by the relative job opportunities in the investment region and the urban region. Figures 5.2 and 5.3 and Table 5.2 show the plots and printout of the main variables (Agricultural Jobs, Rural Unemployment, Rural Population and Rural Migration) that influence population level. Jobs for the first fifteen years (1985-2000) increase slowly (almost static to an average growth of one percent); and from 2000-2010, there is a greater growth, reaching approximately one and one-half percentage. This change is due to the cumulative impact of the improved accessibility over the past fifteen years (1985-2000). From 2010-2015, the growth rate falls to less than one percent and is likely to remain there since the potential arable land area is now more or less occupied, and any new jobs created must be from other sources.

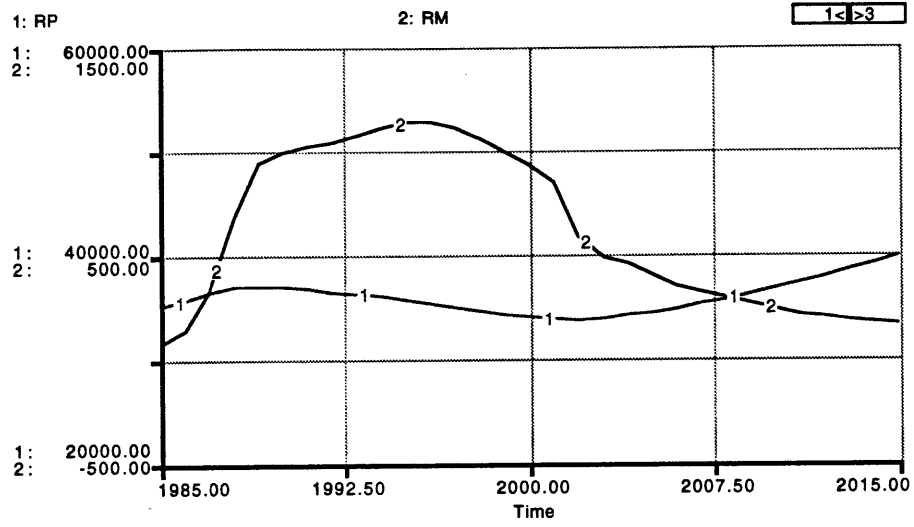


Figure 5.2 The Computer Plot of Rural Population and Migration

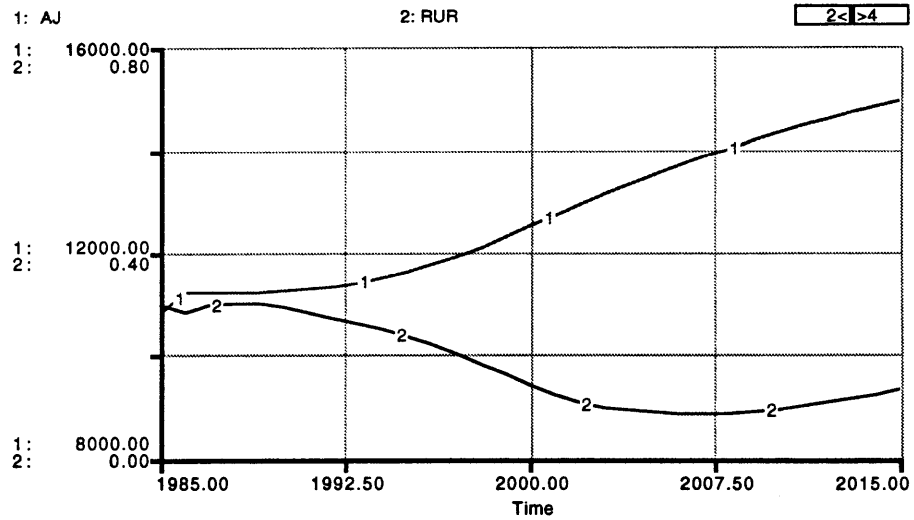


Figure 5.3 The Computer Plot of Rural Jobs and Unemployment Rate

Table 5.2 Computer Printout of the Main Socio-economic Variables

Year	AJ	RUR	RP	RM	UMRL	UMRTR	RTC	
1985.00	10800.00	0.29	35000.00	73.48	0.00	68274.66	98437.50	
1986.00	11195.01	0.28	35696.52	134.77	0.00	57549.39	83355.25	
1987.00	11191.54	0.29	36347.07	323.76	0.00	58672.35	70832.00	
1988.00	11194.16	0.30	36822.95	679.75	0.00	58177.85	58252.72	Legend:
1989.00	11203.93	0.30	36953.31	938.38	0.00	46660.65	46660.65	AJ : Agricultural Jobs
1990.00	11223.31	0.29	36827.90	993.48	11475.47	43370.27	43370.27	RUR : Rural Unemployment Rate
1991.00	11255.23	0.28	36644.64	1024.75	26230.43	43112.07	43112.07	RP : Rural Population
1992.00	11303.71	0.27	36426.07	1042.27	41227.17	43626.60	43626.60	RM : Rural Migration
1993.00	11374.61	0.26	36185.18	1074.66	55723.14	44092.35	44092.35	UMRL : Unmilled Rice
1994.00	11472.75	0.25	35906.59	1113.18	69746.27	44031.71	44031.71	UMRTR : Unmilled Rice Production Loss
1995.00	11591.51	0.23	35583.35	1139.03	83660.36	43756.10	43756.10	RTC : Unmilled Rice Transportation Rate
1996.00	11729.90	0.22	35227.16	1140.90	97758.12	43482.13	43482.13	RTC : Unmilled Rice Transport Capacity
1997.00	11900.31	0.20	34861.25	1111.29	112283.83	43406.69	43406.69	
1998.00	12090.96	0.18	34516.90	1054.01	126840.17	43687.02	43687.02	
1999.00	12293.35	0.16	34222.27	997.11	141141.11	43747.76	43747.76	
2000.00	12501.13	0.14	33978.05	933.25	155532.70	43800.46	43800.46	
2001.00	12709.66	0.12	33792.31	851.55	170138.38	44279.87	44279.87	
2002.00	12915.55	0.10	33684.20	580.62	184593.68	44569.65	44569.65	
2003.00	13116.39	0.09	33844.64	480.26	199128.02	44816.87	44816.87	
2004.00	13312.02	0.09	34108.96	453.72	214163.70	45240.86	45240.86	
2005.00	13501.43	0.08	34405.64	403.82	229610.50	45770.17	45770.17	
2006.00	13683.60	0.08	34758.74	340.89	245346.85	46328.66	46328.66	
2007.00	13857.90	0.08	35182.54	321.32	261323.61	46888.15	46888.15	
2008.00	14023.97	0.08	35635.24	291.05	277514.36	47436.10	47436.10	
2009.00	14181.67	0.09	36128.17	260.10	293900.93	47966.00	47966.00	
2010.00	14331.01	0.09	36662.89	233.12	310468.66	48474.03	48474.03	
2011.00	14472.12	0.10	37236.35	211.36	327204.85	48957.96	48957.96	
2012.00	14605.23	0.10	37844.19	194.50	344098.23	49416.58	49416.58	
2013.00	14730.59	0.11	38482.26	181.75	361138.68	49849.43	49849.43	
2014.00	14848.54	0.12	39147.12	172.31	378317.04	50256.60	50256.60	
2015.00	14959.39	0.13	39836.05	165.53	395624.99	50638.59	50638.59	

However, an interesting feature of the region during this low generation of job opportunities under the "Do Nothing" strategy is that the unemployment rate is falling (the converse of what should be expected). This fall in unemployment rate is due primarily to the heavy out-migration, as shown in Table 5.3 and Figure 5.4, reaching a high point of approximately 1,141 persons in 1996 and gradually decreasing 166 persons in 2015. Migration produces the most significant impact on the rural population level. An outflow of population is experienced between 1990 and 2010 and the region (with an initial population of approximately 35,000) finally stabilizes at a population of approximately 39,800 persons in the year 2015.

Table 5.3 Computer Printout of the Main Spatially Impacted Variables

Year	UPOP	UI	RM	WCADT	NBADT
1985.00	396900.00	4644.58	73.48	5498.38	5940.57
1986.00	408166.06	4825.77	134.77	7134.78	6301.97
1987.00	419811.11	5138.34	323.76	8608.40	6864.76
1988.00	431973.54	5622.94	679.75	9994.43	7566.82
1989.00	444834.95	6016.96	938.38	11339.38	8381.88
1990.00	458317.67	6213.47	993.48	12652.66	9281.80
1991.00	472235.71	6390.30	1024.75	13932.93	10232.86
1992.00	486577.50	6557.42	1042.27	15209.84	11230.10
1993.00	501341.25	6743.42	1074.66	16506.48	12273.66
1994.00	516553.74	6939.80	1113.18	17829.42	13359.02
1995.00	532233.74	7127.91	1139.03	19183.02	14482.45
1996.00	548381.76	7296.44	1140.90	20569.52	15639.56
1997.00	564987.03	7437.77	1111.29	21989.60	16825.42
1998.00	582030.96	7555.49	1054.01	23436.39	18029.94
1999.00	599498.23	7677.53	997.11	24896.55	19238.64
2000.00	617401.20	7796.61	933.25	26369.86	20447.80
2001.00	635745.16	7901.92	851.55	27855.42	21653.18
2002.00	654524.72	7822.02	580.62	29351.50	22849.62
2003.00	673562.94	7915.03	480.26	30844.52	24017.77
2004.00	693037.67	8085.88	453.72	32345.12	25168.86
2005.00	713035.05	8238.17	403.82	33837.85	26291.04
2006.00	733546.46	8382.17	340.89	35292.48	27359.06
2007.00	754573.36	8574.29	321.32	36710.60	28370.90
2008.00	776173.64	8761.03	291.05	38097.82	29329.34
2009.00	798352.79	8952.46	260.10	39456.04	30232.14
2010.00	821126.44	9153.39	233.12	40787.69	31077.36
2011.00	844515.32	9365.29	211.36	42095.23	31862.68
2012.00	868542.01	9588.05	194.50	43380.85	32584.82
2013.00	893229.40	9821.10	181.75	44646.15	33239.22
2014.00	918600.22	10063.87	172.31	45892.37	33834.56
2015.00	944677.05	10315.93	165.53	47121.10	34389.18

Legend:
 UPOP : Urban Population
 UI : Urban In-Migration
 RM : Rural Migration
 WCADT : West Coast Average Daily Traffic (passenger car units)
 NBADT : North Bank Average Daily Traffic (passenger car units)

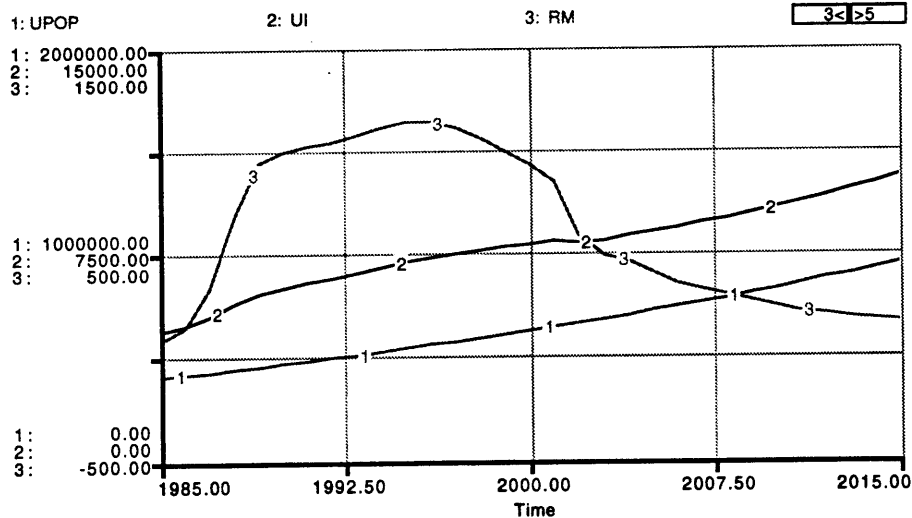


Figure 5.4 The Computer Plot of Main Spatially Impacted Variables

Gross regional income per capita at the beginning of the analysis (i.e., in the year 1985, the population is 35,000 persons; production is 55,000 tons) results in an approximate income per capita of \$3,142 per annum. Gross income per capita at stability or at the time when the potential of the region has been reached (i.e., in the year 2015, the population is 39,800 persons; production is 70,000 tons) is approximately \$3,518 per annum. Both incomes per capita are based on a selling price of \$2,000 per ton for unmilled rice.

Thus, the "Do Nothing" strategy has resulted in heavy urban in-migration and no major changes in the rural region's income per capita in the long run.

Impacts on the Urban Region (Spatial Impacts)

Spatial impacts, as hypothesized in this study, is due primarily to population movements. The influx of people from the rural region increases the urban population, labor force and unemployment rate and creates additional stresses on the urban socio-economic infrastructure of housing and transport among others. Furthermore, the urban region was subdivided into four zones in order to be able to explicitly evaluate zonal impacts of in-migration on transportation per se. The spatial impacts as measured by: (a) urban population, and (b) traffic on the road approaches to Chang-Hwa City (i.e., West Coast and North Bank Pa-Chang-- the zones with direct connection into the capital Chang-Hwa City) are traced and discussed.

Table 5.3 and Figure 5.4 show that the urban population has increased from 396,900 persons (in the year 1985) to 944,677 persons (in the year 2015); and during the same period, overall in-migration has jumped from approximately 4,644 persons per year

in 1985 to approximately 10,315 persons per year in 2015. Of importance, however, is that the "Do Nothing" policy in the Dro-Shu Region has contributed significantly to the overall urban migration (as much as 15%) between the years 1985 to 2010; and not until 2011, when the cumulative impact of the road investment is felt, does this out-migration trend cease. Thus, the "Do Nothing" policy has resulted in "premature" growth in urban population and traffic on the West Coast and North Bank approach roads. The traffic increases are assumed to be directly proportional to the population increase (i.e., each "new resident" generates his share of social and economic trips). Both approaches to Chang-Hwa City are served by a two-lane urban highway (i.e., 12-foot wide lanes and 0.6-foot wide shoulder), resulting in an average capacity of 2000 passenger cars per hour. Further, the peak hour traffic on both approaches is between 8 and 12 percent. Figure 5.5 shows a plot of the approach roads traffic; the North Bank route has reached its peak hour capacity in 1995 and continues to grow to almost 2.5 times the value by year 2015. The West Coast route is even worse. It has reached its capacity in 1992, but stabilizes by 2009 to approximately 6 times its 1985 value. The equilibrium is due primarily to the land constraint of the zone.

The results of this policy run clearly show that the traffic problem of the approach roads to Chang-Hwa City is one of the impacts of rural policies. It is contended that unwarranted in-migration contributed to a deteriorating traffic problem of Chang-Hwa City. Today, the approach roads to Chang-Hwa City are being improved to 4 lanes to cope with the traffic growth.

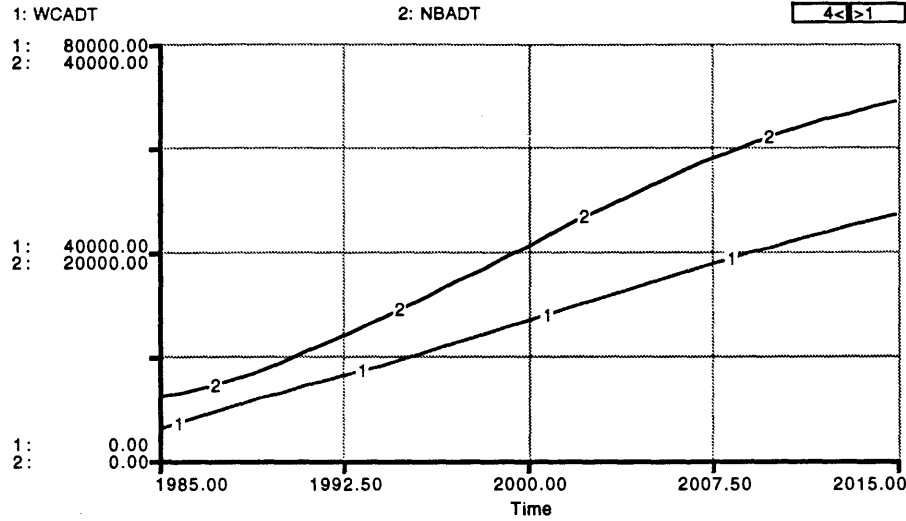


Figure 5.5 The Computer Plot of the Traffic on the Approaches to Chang-Hwa City

5.2. Investment in Roads Alternative

The fact that roads influence the intensiveness and extensiveness of socio-economic activities in Chang-Hwa County was clearly illustrated in Chapter 4 and showed that population distribution and cultivation followed very closely the road infrastructure. This regional behavior is also evidenced in the study region, which has a potential arable area of 70,000 acres, but is cultivated at only just over 30,000 acres for the past ten years (1985-1995) because of an inadequate road network.

Accessibility by road is therefore unquestionably the main perceived bottleneck to the expansion of the agricultural base of the region. The question to be addressed is whether it is feasible to expand the road network and take advantage of the agricultural potential of the region. The remainder of this section addresses the feasibility of investment in "Roads Only".

From a modeling point of view, the only modification required to the "calibrated model developed in Chapter 4 is the removal of the budgetary or funding constraint, as was the case in the "Do Nothing" alternative. This was done by simply re-initializing the model in the year 1995 and providing an input of \$20,000,000 for road expenditure in 1995 (based on proposed investment schedule in the 10-Year Public Development Program developed by Council of Economic Planning and Development, 1994). Thus, the expansion of the road network from the year 1995 and onward is dependent only on the construction capabilities of the system (i.e. the contractor or government and problems of right-of-way access), and no longer on funding. This time lag between funding and the expansion of the road network is reflected in the model by the equation for Road Construction Rate per year as follows:

$$RCR = \text{MIN}(\text{DFR}, \text{RCB}/\text{CCPM}) * \text{RRLAM}/\text{RCT}$$

where:

REC : Road Construction Rate (miles of road per year).

MIN : Minimum function (i.e., number of miles constructed per year is equal to the minimum required or that the budget would permit).

DFR : Demand For Road(miles).

RCB : Road Contraction Budget (in dollars).

CCPM : Construction Cost Per Mile (in dollars).

RRLAM : Rural Road land Availability Multiplier (Dimensionless).

RCT : Road Construction Time (years) (i.e., the time lag between funding and completion).

The behavior was then simulated for another twenty years to the year 2015. The analyses of the behavior of the region over this period is considered as the "Roads Only" investment strategy.

5.2.1 Economic Analyses

Table 5.4 provides the direct computer printout of the main variables needed for the economic analysis. The names and definitions of the variables are similar to those of the "Do Nothing" alternative at ten percent (10%) interest rate for the analyses period from year 1995 to 2015 results in a Net Present Value of road expenditure of approximately \$23,916,265, and the Net Present Value of receipts from farming of approximately \$35,419,113. These cash flows provide a benefit/cost ratio of 1.52 and a net present benefit of approximately \$11,502,848.

Table 5.4 Computer Printout of the Main Variables Used in Economic Analysis

Year	RL	CFA	RROAD	RER	RCE	RME	UMRPR
1995.00	32198.63	223.45	233.47	6019803.00	5326345.00	693458.00	57853.86
1996.00	32583.07	223.53	253.94	6205769.00	5326255.00	879514.00	58540.07
1997.00	33162.87	223.44	270.25	5235472.00	4208695.00	1026777.00	58199.43
1998.00	33843.95	223.35	283.18	3066574.00	1970812.00	1095762.00	57890.09
1999.00	34567.26	223.34	293.39	2011380.00	884622.00	1126758.00	58070.45
2000.00	35295.82	223.35	301.41	1556151.00	414920.00	1141231.00	58423.72
2001.00	36007.22	223.38	307.71	1351952.00	203564.00	1148388.00	58888.06
2002.00	36688.31	223.42	312.63	1252457.00	100595.00	1151862.00	59956.64
2003.00	37339.49	223.45	316.48	1202289.00	48725.00	1153564.00	60992.91
2004.00	37955.21	223.49	319.48	1177373.00	23051.00	1154322.00	61997.34
2005.00	38533.10	223.52	321.82	1165377.00	10588.00	1154789.00	62956.08
2006.00	39072.68	223.55	323.64	1203134.00	48210.00	1154924.00	63861.00
2007.00	39574.69	223.58	325.06	1176641.00	21654.00	1154987.00	64707.84
2008.00	40040.64	223.61	326.16	1155123.00	1025.00	1154098.00	65495.47
2009.00	40472.46	223.63	327.02	1155413.00	404.00	1155009.00	66224.94
2010.00	40872.33	223.65	327.68	1155258.00	241.00	1155017.00	66898.66
2011.00	41242.46	223.67	328.20	1155208.00	182.00	1155026.00	67519.83
2012.00	41585.08	223.69	328.60	1155125.00	92.00	1155033.00	68092.06
2013.00	41902.30	223.70	328.91	1155111.00	71.00	1155040.00	68619.07
2014.00	42196.12	223.71	329.16	1155103.00	58.00	1155045.00	69104.51
2015.00	42468.44	223.72	329.35	1155092.00	44.00	1155048.00	69551.88

Legend:

RL	: Rice Cultivated	CFA	: Cost of Farming Per Acre
RROAD	: Road Miles	RER	: Total Road Expense
RCE	: Road Construction Expense	RME	: Road Maintenance Expense
UMRPR	: Unmilled Rice Production		

5.2.2 Analyses of Other Socio-Economic Regional Indicators

Rarely, if ever, transportation planners would recommend an investment alternative based only on non-quantifiable socio-economic characteristics. However, the premise of this study is that an awareness of the overall socio-economic impact of any investment approach is as equally important as the economic analysis and should be undertaken before final recommendations are made, especially if the economic test is a borderline case. Moreover, when all alternatives are feasible then the socio-economic analyses become even more relevant if negative impacts are to be minimized. The "Road Only" alternative satisfies the feasibility criteria of benefit/cost and net present benefit, and is therefore a viable candidate for overall impact analyses and final consideration.

Impact on Production and Productivity

Figure 5.6 traces the level of road, cultivation and production for the investment in the "Roads Only" police. Within ten years (1995 to 2005), the road network is almost completed. Cultivation reaches its full potential in 2011. The delays between funding (in 1995) and accessibility (completion of network in 2005) and full cultivation (in 2011) are due to the time required for road construction and land development.

Expansion of the road network has resulted in approximately 8.8 percent (50%) increase in production (from 57,000 tons to 62,000 tons) within ten years (from 1995 to 2005). From Table 5.4, productivity (UMRPR/RL) (i.e., yield per acre) has remained constant over the analysis period at approximately over 1.6 ton per acre. This is not surprising since yield per acre is determined by several factors including drainage and irrigation availability. The "Roads Only" investment strategy in no way improves the

drainage and irrigation level. If any, the increased acreage has effectively reduced the water availability per acre cultivated. However, the expansion of the network has significantly impacted the timing of the receipts from agricultural expansion.

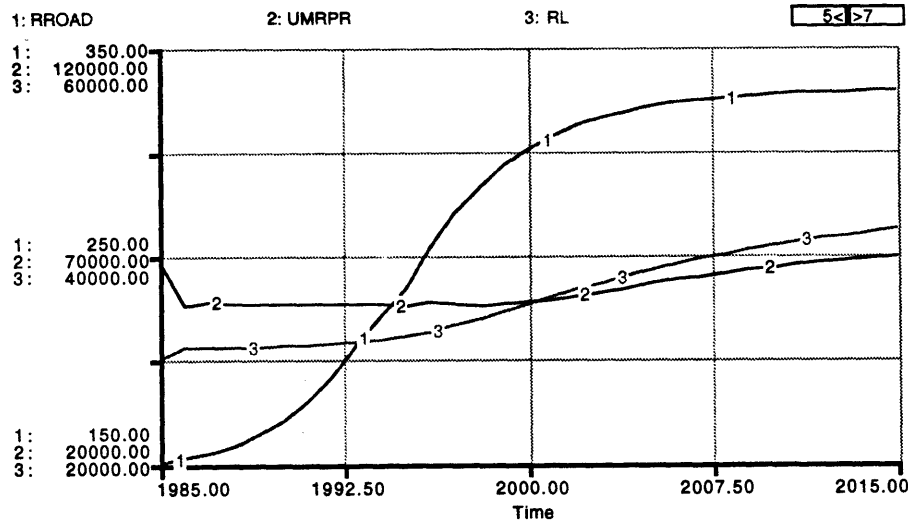


Figure 5.6 The Computer Plot for the Main Economic Variables - Roads, Cultivated, and Production - Roads Only

Impact on Population and Income Per Capita

Jobs influence migration and migrations the most significant impact on rural population level. The expansion of the rural road network has resulted in increased cultivation; within five years (1995-2000), job opportunities grew from 11,591 to 12,706 - a ten percent increase (see table 5.5 and Figure 5.7). Big decrease of out-migration occurred after year 2000 due to a combination of the impacts from road construction and agricultural cultivation. In the same period (2001-2015), rural population increased to 40,763 from 34,175 persons, indication the potential of the region to provide a livelihood for its population; also, unemployment reached its lowest level of approximately eight

percent (8%) between years of 2005 and 2008. Gross regional income per capita rose to \$3,446 based on production and population levels in 2001 (i.e., 58,888 ton and 34,175 persons). Thus, the socio-economic characteristics of the rural region have been propitiously impacted.

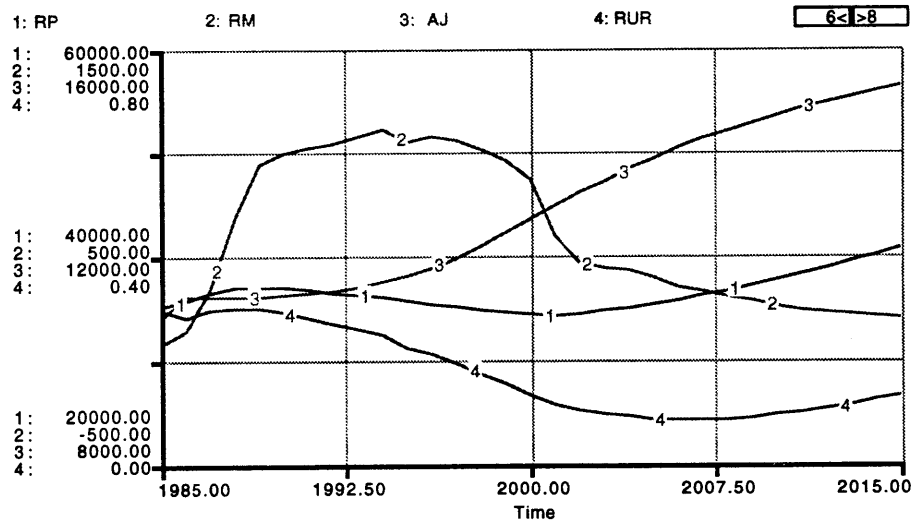


Figure 5.7 The Computer Plot of the Main Socio-Economic Variables - Roads Only

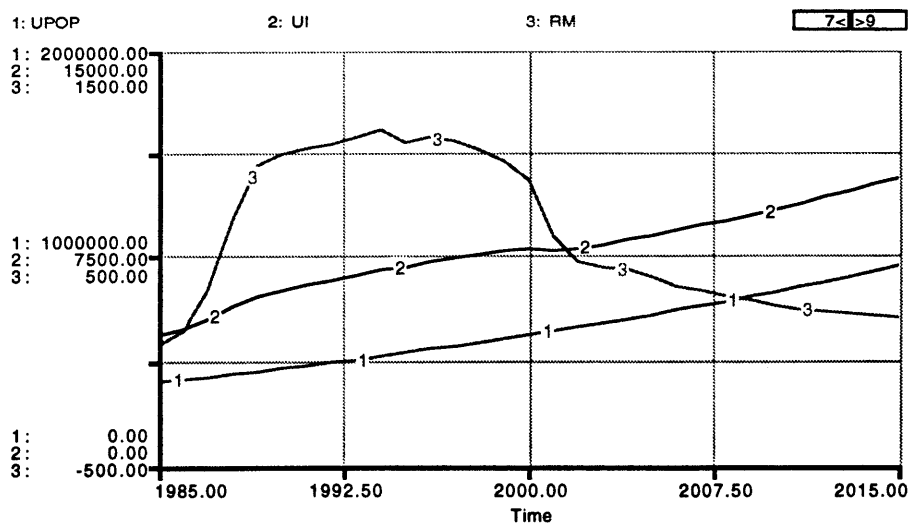


Figure 5.8 The Computer Plot of the Main Spatially Impacted Variables - Roads Only

Table 5.5 Computer Printout of the Main Variables Used in Analysis

Year	RP	RM	AJ	RUR	UPOP	UI	NBADT	WCADT
1995.00	35583.35	1049.65	11591.51	0.22	532233.74	7038.54	14643.72	19344.29
1996.00	35316.53	1075.35	11729.90	0.21	548292.38	7230.03	15798.06	20729.58
1997.00	35018.15	1054.29	11938.63	0.19	564829.58	7379.26	16983.04	22150.07
1998.00	34734.25	1014.24	12183.82	0.17	581812.07	7513.63	18187.38	23597.87
1999.00	34484.17	952.44	12444.21	0.15	599233.40	7630.32	19397.42	25060.22
2000.00	34290.38	868.86	12706.50	0.13	617084.23	7729.19	20607.57	26535.43
2001.00	34175.91	593.09	12962.60	0.11	635354.86	7639.75	21812.30	28021.61
2002.00	34334.68	460.30	13207.79	0.10	653864.96	7695.45	22991.11	29505.08
2003.00	34629.75	433.95	13442.21	0.09	672764.25	7861.17	24153.41	30994.50
2004.00	34957.65	426.16	13663.87	0.09	692170.15	8050.12	25305.16	32496.49
2005.00	35300.56	392.46	13871.92	0.08	712115.51	8218.14	26429.99	33992.17
2006.00	35684.71	347.43	14066.16	0.08	732589.63	8379.70	27502.42	35451.08
2007.00	36122.35	328.87	14246.89	0.08	753596.09	8572.63	28520.61	36874.96
2008.00	36588.17	303.01	14414.63	0.08	775176.37	8763.60	29485.88	38268.28
2009.00	37090.10	277.49	14570.09	0.09	797339.35	8960.30	30396.28	39633.18
2010.00	37628.60	255.54	14714.04	0.09	820101.80	9166.17	31249.95	40972.16
2011.00	38200.88	237.87	14847.29	0.10	843484.22	9382.10	32044.54	42287.67
2012.00	38803.43	224.10	14970.63	0.10	867508.34	9607.92	32776.70	43581.83
2013.00	39433.01	213.56	15084.83	0.11	892196.18	9843.19	33441.81	44856.18
2014.00	40086.97	205.64	15190.60	0.12	917569.67	10087.49	34048.06	46111.89
2015.00	40763.25	199.83	15288.64	0.13	943650.78	10340.56	34614.01	47350.51

Legend:

RP	: Rural Population	RM	: Rural Migration
AJ	: Agricultural Jobs	RUR	: Rural Unemployment Rate
UPOP	: Urban Population	UI	: Urban In-migration
NBADT	: North Bank Average Daily Traffic	WCADT	: West Coast Average Daily Traffic

Impacts on the Urban Region (Spatial Impacts)

Table 5.5 and Figure 5.8 show that overall urban in-migration rose from approximately 7,038 persons in 1995 to approximately 10,340 persons in the year 2015; but of real significance here is that the Dro-Shu Region has contributed to less than three percent (3%), as opposed to as much as fifteen percent (15%) in the "Do Nothing" alternative. In fact, during the period 1996-2016, the investment in road strategy has relieved the "population pressure" on the urban region through rural in-migration. Again, the impact on the approach roads traffic is proportionately reduced due to a reduction in urban in-migration. Figure 5.9 shows that the North Bank Road Approach reaches stability in the year 2013, five years later than the "Do Nothing" strategy; while a similar (or proportionate) reduction is observed on the West Coast Road Approach.

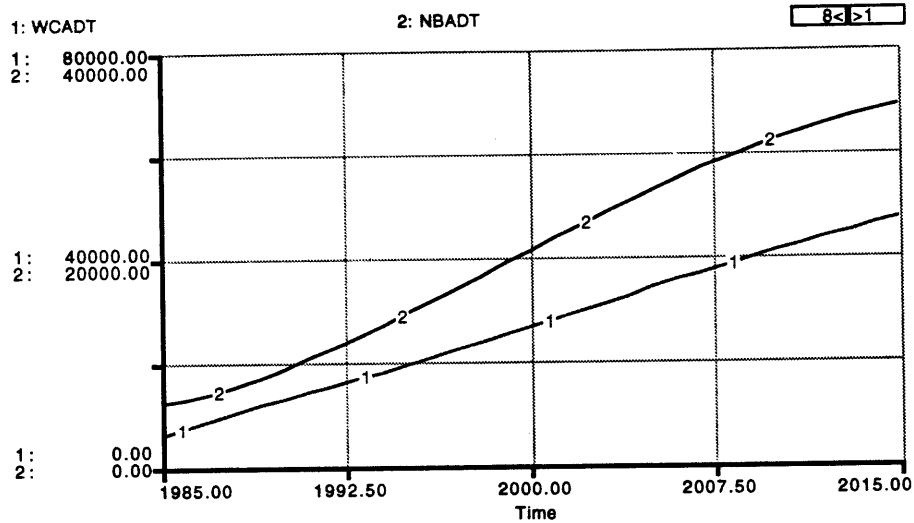


Figure 5.9 The Computer Plot of the Traffic Flow on the Chang-Hwa City Approaches

5.3 Investments in Roads, Drainage and Irrigation Alternative

Because of the positive impacts (attested to from empirical evidence), resulting from road investment in many poorly accessible regions of DCs, there is the belief that road or transportation per se is the answer to the development problem. The concept that road equals development is especially misleading in agricultural expansion schemes. There is no doubt that road is the main catalyst to the initial expansion, but sustained and continue growth and productivity depend on other inputs of which "dependable" drainage and irrigation may be as equally important as roads. Roads provide primarily access and reduction in the cost of transportation of input and outputs to and from the farm. However, the rate at which inputs (such as fertilization, mechanization, husbandry, etc.) are introduced to farming depends on the farmers' perception of their crops, free from the threat of droughts or floods (i.e., drainage and irrigation) of the region. Simply put, "dependable" drainage and irrigation constraint and incorporate the time lag needed to

construct the increased drainage and irrigation capacity. This is done by changing the rate equation for drainage and irrigation inputs form:

$$R \quad IWAR = 0$$

to $R \quad IWAR = \text{STEP}(156000, 2002) - \text{STEP}(156000, 2003)$

where:

IWAR : Drainage and Irrigation Rate (acre feet/year)

STEP : This is a function that explicitly incorporates a change in the reservoir capacity by 156000 acre feet in 2002 and maintains a zero growth rate after 2002. (Thus, the new drainage and irrigation capacity after 2002 is equal to the initial capacity of 156000 acre feet plus the expansion of 156000 acre feet between 1995 to 2002).

The modified model was then simulated to the year 2015, and the analyses of the performance of the region over this period is considered as the impacts of the "comprehensive" investment strategy. The disbursement for drainage and irrigation, as shown in Table 5.6, is over a seven-year period (funding for drainage and irrigation was not explicitly incorporated in the model).

5.3.1 Economic Analyses

Tables 5.6 and 5.7 provide the data and summary of the calculation and values of the benefit/cost ratio and net present benefits for the "Roads, Drainage and Irrigation" alternative. These cash flows of a Net Present Value of expenditure of approximately \$41,784,665 in roads and drainage and irrigation infrastructure, and a Net Present Value

receipts from farming of \$65,081,055, result in a benefit/cost ratio of 1.59 and a net present benefit of \$23,233,390.

Table 5.6 Computer Printout of the Main Variables Used in Economic Analysis

Year	RL	CFA	RROAD	RER	RCE	RME	UMRPR
1995.00	32198.63	223.45	233.47	6019803.00	5326345.00	693458.00	57853.86
1996.00	32583.07	223.53	253.94	6205769.00	5326255.00	879514.00	58540.07
1997.00	33162.87	223.44	270.25	5235472.00	4208695.00	1026777.00	58199.43
1998.00	33843.95	223.35	283.18	3066574.00	1970812.00	1095762.00	57890.09
1999.00	34567.26	223.34	293.39	2011380.00	884622.00	1126758.00	58070.45
2000.00	35295.82	223.35	301.41	1556151.00	414920.00	1141231.00	58423.72
2001.00	36007.22	223.38	307.71	1351952.00	203564.00	1148388.00	58888.06
2002.00	36688.31	223.42	312.63	1252457.00	100595.00	1151862.00	59956.64
2003.00	37339.49	223.45	316.48	1202289.00	48725.00	1153564.00	69074.57
2004.00	38253.39	223.34	319.48	1177373.00	23051.00	1154322.00	69072.80
2005.00	38883.87	223.46	321.82	1165377.00	10588.00	1154789.00	70781.71
2006.00	39627.36	223.44	323.64	1203134.00	48210.00	1154924.00	71350.24
2007.00	40238.01	223.50	325.06	1176641.00	21654.00	1154987.00	72585.94
2008.00	40884.76	223.50	326.16	1155123.00	1025.00	1154098.00	73287.57
2009.00	41452.94	223.54	327.02	1155413.00	404.00	1155009.00	74269.31
2010.00	42006.77	223.56	327.68	1155258.00	241.00	1155017.00	75028.53
2011.00	42512.85	223.59	328.20	1155208.00	182.00	1155026.00	75833.86
2012.00	42986.83	223.61	328.60	1155125.00	92.00	1155033.00	76551.71
2013.00	43428.09	223.63	328.91	1155111.00	71.00	1155040.00	77225.05
2014.00	43845.60	223.64	329.16	1155103.00	58.00	1155045.00	77829.49
2015.00	44236.18	223.65	329.35	1155092.00	44.00	1155048.00	78404.49

Legend:

RL	: Rice Cultivated	CFA	: Cost of Farming Per Acre
RROAD	: Road Miles	RER	: Total Road Expense
RCE	: Road Construction Expense	RME	: Road Maintenance Expense
UMRPR	: Unmilled Rice Production		

Table 5.7 Summary of Calculation for Economic Analysis of Road, Drainage and Irrigation Alternative

Drainage Irrigation Cash Flow (D and I)	Present Value of D and I	Present Value of Road Expenses	Present Value of Net Farm Income
\$2 Million(1995)			
\$5 Million(1996)	\$17,868,400	\$23,793,390	\$55,121,500
\$5 Million(1997)			
\$5 Million(1998)			
\$5 Million(1999)			
\$2 Million(2000)			
\$1 Million(2001)			
<hr/>			
Benefit/cost (B/C) = 1.32 Net Present Value (NPV) = \$13,514,000			

5.3.2 Analyses of Other Socio-Economic Indicators

Impacts on Production and Productivity

Figure 5.10 and Table 5.6 trace the growth of road, cultivation and production between the period 1995-2015. Within ten years, cultivation reached its total potential from 58,853 tons to 70,781 tons, resulting in an average yield of 1,82 tons per acre.

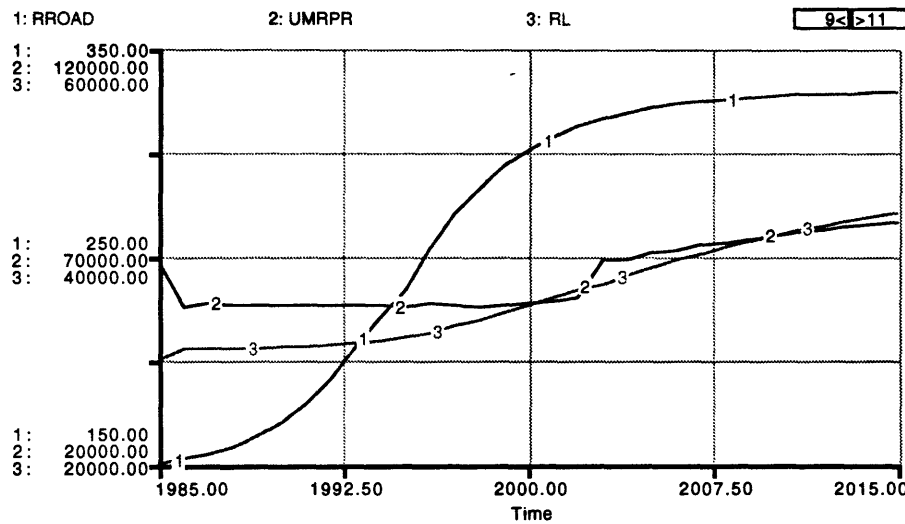


Figure 5.10 The Computer Plot of the Main Economic Variables - Road, Cultivation, Production - Comprehensive Strategy

Impacts on Population and Income Per Capita

The hypothesis is that job availability depends on the expansion of the agricultural base (i.e., the rice industry). Furthermore, the expansion of the rice industry depends primarily on accessibility (i.e., the road network); and since this alternative involves the expansion of the road network, then it would be expected that population growth would be similar to the "Roads Only" strategy. Production and productivity, however, depend strongly on drainage and irrigation. Table 5.6 and figures 5.10 and 5.11 show that

production of rice has jumped from approximately 57,800 tons in 1995 to approximately 78,400 tons in 2015, an almost thirty-six percent (36%) increase. The population during the same period rose to 42,101 persons in 2015, resulting in a gross regional income pre capita of approximately \$3,725. Thus, the combined investment strategy shows significant benefits to rural household income.

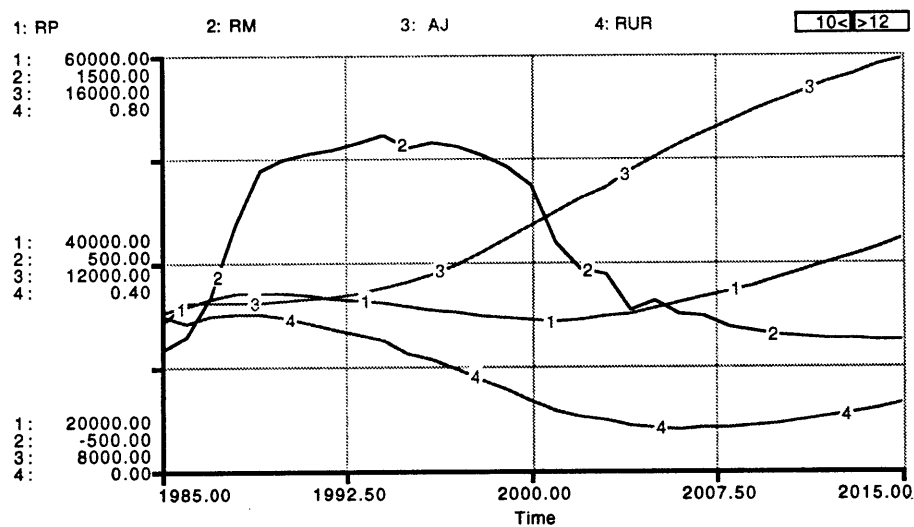


Figure 5.11 The Computer Plot of the Main Socio-Economic Variables - Comprehensive Strategy

Impacts on the Urban Region (Spatial Impacts)

Again, the hypothesis is that population movements determine spatial impacts, and since the growth trend of the population of the "Roads, Drainage and Irrigation" alternative is similar to the "Roads Only" policy, then the discussion of the spatial impacts of the "Roads Only" policy applies here. Table 5.8 and Figures 5.12 and 5.13 support this point of view (i.e., socio-economic spatial impacts are similar).

Table 5.8 Computer Printout of the Main Socio-Economic Variables

Year	RP	RM	AJ	RUR	UPOP	UI	NBADT	WCADT
1995.00	35583.35	1049.65	11591.51	0.22	532233.74	7038.54	14643.72	19344.29
1996.00	35316.53	1075.35	11729.90	0.21	548292.38	7230.03	15798.06	20729.58
1997.00	35018.15	1054.29	11938.63	0.19	564829.58	7379.26	16983.04	22150.07
1998.00	34734.25	1014.24	12183.82	0.17	581812.07	7513.63	18187.38	23597.87
1999.00	34484.17	952.44	12444.21	0.15	599233.40	7630.32	19397.42	25060.22
2000.00	34290.38	868.86	12706.50	0.13	617084.23	7729.19	20607.57	26535.43
2001.00	34175.91	593.09	12962.60	0.11	635354.86	7639.75	21812.30	28021.61
2002.00	34334.68	460.30	13207.79	0.10	653864.96	7695.45	22991.11	29505.08
2003.00	34629.75	433.95	13442.21	0.09	672764.25	7861.17	24153.41	30994.50
2004.00	34957.65	259.43	13771.22	0.08	692170.15	7883.40	25305.16	32496.49
2005.00	35467.29	305.52	13998.19	0.08	711948.79	8129.65	26415.27	33980.60
2006.00	35942.05	241.34	14265.85	0.08	732331.26	8271.21	27479.77	35433.11
2007.00	36491.43	231.56	14485.68	0.08	753224.35	8471.88	28488.27	36849.06
2008.00	37062.68	178.77	14718.52	0.08	774696.84	8634.91	29444.57	38234.87
2009.00	37699.29	164.01	14923.06	0.08	796722.05	8841.12	30343.66	39590.16
2010.00	38364.67	141.60	15122.44	0.09	819353.62	9045.32	31186.99	40920.04
2011.00	39067.10	133.05	15304.63	0.09	842600.99	9269.13	31971.27	42226.19
2012.00	39793.52	126.46	15475.26	0.10	866495.38	9500.95	32694.04	43511.40
2013.00	40542.52	122.80	15634.11	0.11	891057.02	9741.94	33350.53	44777.07
2014.00	41311.65	118.99	15784.42	0.12	916307.63	9989.24	33948.83	46024.32
2015.00	42101.52	117.34	15925.03	0.12	942266.49	10245.36	34507.37	47254.44

Legend:

- RP : Rural Population
- AJ : Agricultural Jobs
- UPOP : Urban Population
- NBADT : North Bank Average Daily Traffic
- RM : Rural Migration
- RUR : Rural Unemployment Rate
- UI : Urban In-migration
- WCADT : West Coast Average Daily Traffic

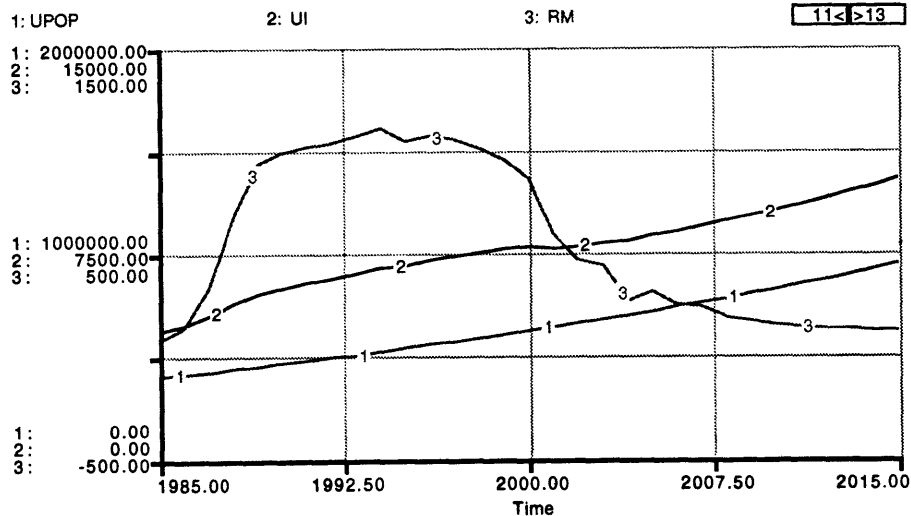


Figure 5.12 The Computer Plot of the Main Spatially Impacted Variables - Comprehensive Strategy

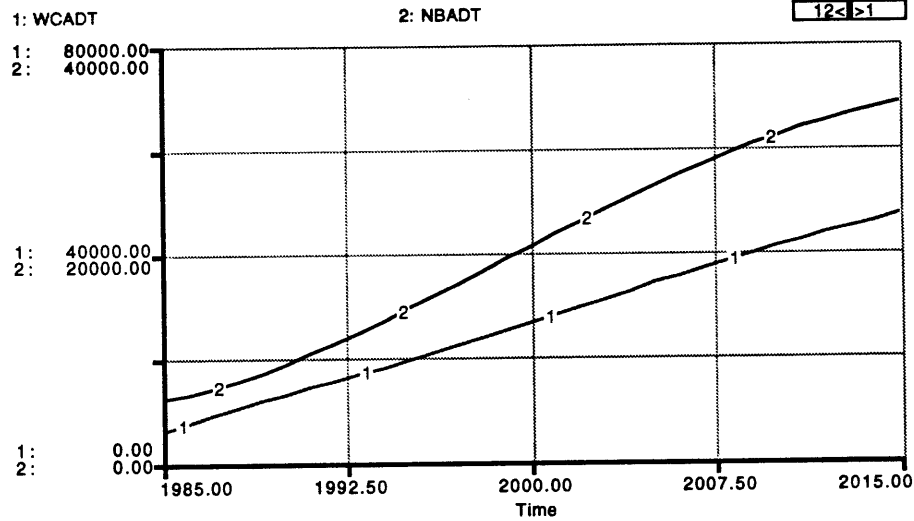


Figure 5.13 The Computer Plot of the Traffic Flows on the Road Approaches to Chang-Hwa City - Comprehensive Strategy

5.4 Comparison of Impacts of Alternative Investment Strategies

The ultimate objective of transportation planning and modeling is to provide decision makers with information that would help in determining future investment in transportation and related economic infrastructure. Thus it would seem obvious that such an information base should contain some advice on the overall impacts (social and economic) of a particular policy on the region and the nation as a whole. Yet, it is not done; and almost invariably, decisions are based on the monetary impacts of a given strategy of investments, which very often result in severe adverse national impacts.

Table 5.9 provides the results of the economic analyses of the three investment policies for the rural region for a 20-year period at ten percent (10%) annual interest rate. All three policies satisfy the minimum criteria of Net Present Value and benefit/cost ratio required for project acceptance. The "Do Nothing" alternative has the highest benefit/cost

ratio, and a significant Net Present Value. In a situation of "financial difficulties," it would seem to be the obvious choice. Furthermore, it might be reasonable to conclude that if only the information provided in Table 5.9 were to be presented to a decision maker (in a scenario of limited resources, as characterized by most DCs), it is more than likely that the "Do Nothing" alternative would be selected for the next twenty years. For sure, in most traditional economic evaluation techniques, the information provided in Table 5.9 is all that would be available to decision makers.

Table 5.9 Results of the Economic Analyses of Three Strategies*

Strategies	Present Value		Net Present Value	Benefit/Cost Ratio
	Roads	Drainage & Irrigation		
1. Do Nothing	\$21,605,880	--	\$13,050,260	1.62
2. Roads Only	\$23,916,265	--	\$11,502,848	1.52
3. Roads, Drainage & Irrigation	\$23,916,265	\$17,868,400	\$23,233,390**	1.59**

* Results based on 20-year simulation at 10% annual interest rate and one crop per year.

** Given guaranteed drainage and irrigation, double cropping per year will result in increased benefits (by a factor of 1.6 to 2.0).

The use of System Dynamics Methodology provides not only the information concerning the traditional economic analyses, as is the case in Table 5.9, but also a time series information on the pertinent socio-economic factors that influence both regional and national performance (e.g., standard of living and utilization of resources) which may be much more important to decision makers.

Table 5.10 Steady State Values for the Main Socio-Economic Indicators

Indicators	Do Nothing	Roads	Roads, Drainage & Irrigation
Rural Roads (Miles)	324	330	330
Rice Land Cultivated Acres	43,158	42,468	44,236
Unmilled Rice Production (Tons)	70,609	69,551	78,404
Gross Regional Income (\$)	138,384,048	140,469,298	156,826,225
Population	39,836	40,763	42,101
Gross Regional Income Per Capita (\$)	3,518	3,446	3,725
Unemployment Rate (%)	13	13	12
Out-Migration (Person/Year)	166	200	117
Out-Migration*	933	868	868
Gross Regional Income Per Capita (\$)*	3,555	3,975	3,991

* Transient state values for 2005.

Table 5.10 provides the information on the main regional socio-economic indicators at steady state (i.e., that point in time when the regional output stabilizes, or further growth in production depends on inputs other than land area farmed or such economic infrastructure as roads, drainage and irrigation). Once again, the "Do Nothing" alternative performance is impressive at "steady state". The main socio-economic indicators of income per capita, regional unemployment rate, and jobs provided suggest that decision makers should leave things as they are (i.e., continue with the status quo). This is, unfortunately, the very type of conclusion that is usually drawn when using "horizon year" projections for developmental projects. In twenty years, there is an obvious convergence of behavior that makes investments in economic infrastructure in poorly accessible regions "seem" infeasible or less attractive than the continuation of the status quo or "Do Nothing" policy.

This is an excellent example of where aggregation (i.e., averaging of impacts to a horizon for economic evaluation) in the traditional economic evaluation techniques gives misleading conclusions; and furthermore, when the aggregation is removed, the results or conclusions of such evaluation techniques fall to pieces. As mentioned in Section 3.1.2 and the foreword of this chapter, an project evaluation should contain a set of socio-economic characteristics rather than a single numerical indicator or only economic factors.

The above phenomena can be illustrated by values for two key socio-economic indicators -- out-migration and gross region income per capita -- for the year 2005. In Table 5.10, these two indicators illustrate quite clearly the superiority of both the "Roads Only" and "Roads, Drainage and Irrigation" policies. In 2005, the Do Nothing" policy has the least income per capita and a highest out-migration. Further, the high income per capita and low unemployment rate are outcomes of the heavy rural out-migration under this strategy. Both capital intensive investment strategies provide the least negative national and regional impacts; and the comprehensive investment alternative (Roads, Drainage and Irrigation) is undoubtedly the most beneficial (i.e., making full use of the regional potential; reversing the adverse national spatial impacts, and increasing regional output greatly).

Chapter 6

Shadow Prices, Sensitivity Analysis and Data Base

In scenarios of high unemployment, rapid inflation and poor data base (characteristics of most DCs), the values (data) or prices (costs) used in the economic analyses of capital intensive projects are often modified to reflect "true social" costs, benefits and risks. The concepts of "shadow prices" and "sensitivity" analyses" are two such techniques used to adjust the profitability of developmental projects. This chapter is, based on these two techniques' discussion and application, then to determine which of the variables "drives" the model in order to identify a more appropriate data base for future model building and planning. Section 6.1 will briefly discuss the concept of "shadow prices" and its relevance to this study. In Section 6.2, extensive sensitivity analyses will be undertaken on the main hypotheses used for the developed model. Those variables on which the model's output sensitivity depends would form the core of the data base and be recommended for further pre- and post-project implementation, investigation and analyses.

6.1 Shadow Prices

The underlying concept of shadow prices is fundamental to economics. They are the prices at which supply is just sufficient to satisfy demand (Tinbergen, 1958). Under conditions frequently encountered in the advanced competitive economies, shadow prices are for the most part similar to market prices, and adjustments are seldom made. But, in a number of developing countries, the market price structure is not a correct guide for taking decisions. The shadow price of a factor is therefore a measure of its opportunity

cost or its marginal product. The literature reveals that shadow prices have been used at two distinct levels of analysis. One is involved with theoretical concepts which have strict mathematical and economic meaning; and the other is intuitive and applied (Tinbergen, 1958).

The Theoretical Approach

Theoretically, shadow prices can be determined if a continuous production function of the Cobb-Douglas (Jones, 1975; and Cobb and Douglas, 1928) form is assumed and an optimal technology is found. The form of the production function is as follows:

$$Y = K^{\alpha} L^{\beta}$$

This equation states that the aggregate output Y is a function of the amount of capital, K, and Labor, L, in the economy and α and β are empirically determined constants.

The optimal technology is one which would:

"... absorb the factors in proportion in which they are available. And by increasing the level of production, we can reach the point all the factors are fully utilized and yield the maximum values of output." (Grant, 1960)

Qayum (1960) suggests the use of partial differentiation to determine the shadow prices of wages and capital as follows:

Let R be the net return which is to be maximized; C the costs; p the value of outputs; and $\alpha + \beta = 1$. Then, using the Cobb-Douglas function, we have:

$$R = pY - C = pL^{\alpha} K^{1-\alpha} - C$$

then, the partial derivative of R with respect to L:

$$\partial R / \partial L = p\alpha(L/R)^{\alpha-1} \quad (\text{is the shadow price of labor})$$

and the corresponding shadow costs of capital is the partial derivative of R with respect to K:

$$\partial R / \partial K = p(1-\alpha)(L/K)^{\alpha-1}$$

Another approach for determining shadow prices is through the use of linear programming. Given the optimal technology, alternative methods of production, resources and constraints, the solution to the "dual" problem provides the respective shadow values.

Intuitive or Empirical Approach

The above stringent theoretical approaches and their concomitant limitations (i.e., the uses of (1) the abstract-continuous production function; and (2) fixed coefficients) have resulted in most analysts resorting to intuitive and/or empirical approaches. One of the most widely used techniques for adjusting project values to reflect "social" costs and benefits is sensitivity analysis -- the subject of the next section.

6.2 Sensitivity Analyses

Grant and Ireson (1960) define sensitivity analysis as follows:

"Sensitivity refers to the relative magnitude of the change in one or more element of an engineering economy problem that will reverse a decision among alternatives."

and further recommend the use of sensitivity analysis by saying:

". . . Since all estimates are subject to some amount of uncertainty, the sensitivity approach may be very helpful in analyzing a proposal or set of

proposals. The application of the sensitivity concept becomes an intermediate step between the numerical analysis based on the best estimates for the various elements and the final decision. Each element can be tested to see how sensitive the decision is to variations from the best estimate, and the results used in the final decision-making process."

Even though these statements are made with regard to decision among alternatives, it is felt that the concept can be used to test the validity of data and assumptions made within a single model, and also to identify those factors on which regional performance most sensitively depends.

6.2.1 The Use of Sensitivity Analysis in This Study

The traditional use of sensitivity analysis to adjust for the "true" or "marginal cost" of labor (i.e., wages) and capital (i.e., interest rate) is not specifically undertaken in this study for the following main reason.

First, in the case of labor, it is difficult to identify an appropriate adjustment factor for wages in scenarios of high unemployment, as is the situation in the case study -- since by definition "the social opportunity cost of labor", the term used in project evaluation, is equivalent to cost of production, foregone in another sector by the use of the labor in the proposed project. Defined this way, the opportunity cost of labor will be positive when there is full employment, but if there is unemployment, it should be possible to employ labor on the project without having to withdraw it from elsewhere. Thus, the opportunity cost of labor may well be zero in an economy with unemployment (Grant and Ireson, 1972). Does this mean that employment of labor is costless in an economy with unemployment? The actual wages paid is the true financial cost that must be ultimately

funded by the nation irrespective of the factor used for shadow prices analyses; and therefore, the actual costs should be used for project evaluation.

Secondly, in the case of capital, the choice of 10 percent is considered representative of the interest rate that is likely to be charged for developmental projects in DCs (if anything else, it is likely to be lower rather than higher).

Thirdly, and probably most important, it is felt that no amount of rigorous sensitivity analyses (i.e., in terms of shadow prices for wages and capital) performed on essentially suspect the economic benefits of an investment strategy. Such "economic analyses" are after the "fact" (i.e., output or production is unchanged); and mathematics is then used to justify marginal investment strategies.

A case is not made here against the overall use of shadow pricing. On the contrary, in cases where projects' economic feasibility is strongly influenced by cost of capital and labor, shadow prices analyses are recommended and should be undertaken, since these analyses provide insights into the "true" cost of the projects and a further guide to improved decision-making.

Instead, the concept of sensitivity analysis is used to : (a) test the significance of the model's hypotheses (i.e., interactive structural formulation); and (b) identify the data base that is most pertinent to the socio-economic analyses of rural investment policies in transportation and related infrastructure.

The premise of this study is as follows: (1) the impacts from the investment strategies is not strongly based on the marginal costs from transportation per se; but more on the removal of "bottlenecks" to the expansion of production and productivity of the

region; (2) transportation is but only one of the main resources needed for increased regional production; and (3) there is significant movement of population between relatively developed regions in DCs.

The hypotheses were as follows: (1) roads accessibility; (2) drainage and irrigation; (3) fertilizer; (4) mechanization and technology which dynamically interact to influence production and productivity; and (5) relative regional unemployment rate influences population shifts. The impact of not explicitly (i.e., dynamic modeling) considering the availability of the above resources and the unemployment characteristics of the regions is investigated through sensitivity analyses.

6.2.2 The Sensitivity Tests and Their Results

The sensitivity test procedure is as follows: (1) the investment strategy in "roads, Drainage and Irrigation" is used as the base scenario against which the availability (i.e., the inclusion or exclusion) of the other main resources are tested for their impacts on production; and (2) the linkage of the two regions (rural and urban) is removed, and the impacts of rural unemployment rates are analyzed for representatives.

Test No. 1 -- drainage and irrigation not available -- was done in the model by simply removing the investment in drainage and irrigation. Table 6.1 shows that production drops by as much as 25 percent from 78,404 tons to 69,511 tons per crop for approximately the same cultivation level. This unquestionably indicates that drainage and irrigation are bottlenecks to increase production and productivity.

Test No. 2 -- limited mechanization (i.e., not readily available) -- was done in the model by holding the mechanization multiplier constant at a value of 1. Table 6.1 shows

that even with drainage, irrigation, roads and husbandry, production drops by as much as 11 percent, reflecting the unique roles of machinery (i.e., tractors and harvesters) on overall production.

Test No. 3 -- limited fertilizer -- was performed under two scenarios: (a) fertilizer available at pre-project expansion rate only (i.e., the fertilizer availability multiplier FEAMT = 1.0); and (b) at one and one-half times the pre-project expansion rate (i.e., FEAMT = 1.5). Table 6.1 shows that for case (a), production drops by a staggering 51 percent; in case (b), production drops only approximately 19 percent. Both scenarios indicate the dramatic significance of fertilizer inputs to farming.

Table 6.1 The Impacts on Production Under Various Assumed Resource Availability in the Region

Impacts at End of Simulation - Year 2015			
Tests	Area Cultivated (Acres)	Production Rate (Tons)	Percent Change (%)
Base Scenario (All Resources Available)	44,236	78,404	--
Test 1: No Drainage & Irrigation	42,468	69,511	-11.3
Test 2: Mechanization	41,754	69,882	-10.9
Test 3: Limited Fertilizer			
(a) FEAMT = 1.0	32,247	38,648	-50.7
(b) FEAMT = 1.5	42,151	63,499	-19.0
Test 4: No Drainage, Irrigation, Mechanization or Fertilizer	32,168	32,624	-53.1

The results of Test No. 4 -- the restriction of drainage, irrigation, fertilizer, mechanization and technology (i.e., only roads investments provided) -- in Table 6.1 show that production dropped dramatically from 78,404 tons to 32,624 tons, a 53 percent reduction; and cultivation reached only 32,168 acres by year 2015. This test proved quite conclusively the need for the explicit incorporation of the main resources. A tacit allowance for the availability of these resources overstates the impacts of road investments on rural cultivation and production rate.

The idea of Test No. 5 -- the significance of trucking availability on after-production loss as measured by the variable Unmilled Rice Loss (UMRL) -- is that very often, transportation planners are concerned with the need of the physical infrastructure (i.e., in this case, the miles of roads needed); and the concomitant rolling stock (i.e., trucks, etc.) would be provided. Figure 6.1 shows the plots of the possible impacts of the three investment strategies on after-production losses if the adequate truck fleet is not provided. (Recall, as previously stated, this is not a total loss of tonnage of production; but the amount of production that will not have transportation at the right time and is likely to suffer from spoilages of as much as 10 percent).

The initial trucking fleet of 12 trucks is incapable of meeting the transport demand for the cumulative impacts of the three investment strategies. The comprehensive investment strategy shows the highest loss (approximately 22,000 tons in the year 2005 and thereafter). To avoid these losses, the trucking fleet should be increased by 3, 5 and 10 trucks respectively for the "Do Nothing" , "Roads Only" and "Roads, Drainage and Irrigation" investment strategies by the year 2000.

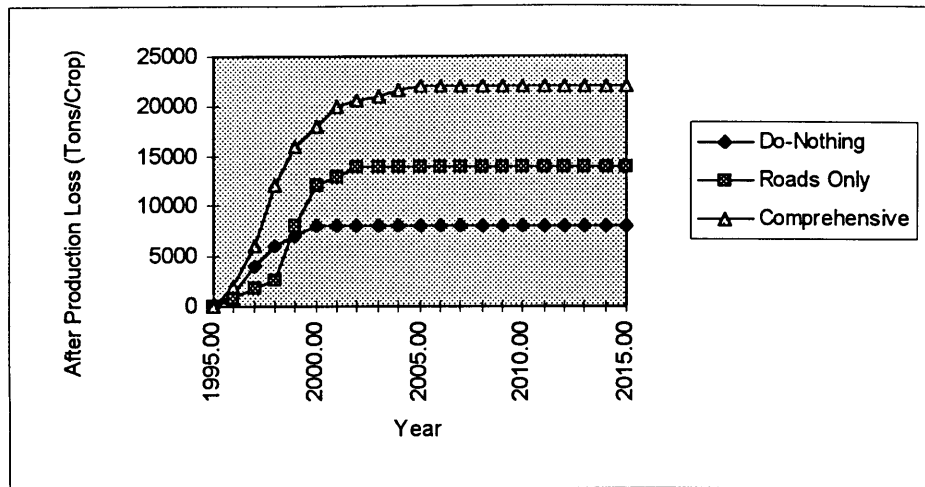


Figure 6.1 Plot of After Production Loss For Three Investment Strategies

The initial trucking fleet of 12 trucks is incapable of meeting the transport demand for the cumulative impacts of the three investment strategies. The comprehensive investment strategy shows the highest loss (approximately 22,000 tons in the year 2005 and thereafter). To avoid these losses, the trucking fleet should be increased by 3, 5 and 10 trucks respectively for the "Do Nothing" , "Roads Only" and "Roads, Drainage and Irrigation" investment strategies by the year 2000.

In Test No. 6 -- the road network adequacy for crop exploitation -- 5.5 miles of road infrastructure was assumed to be the required need for the development of 1,000 acres of rice land. What would happen if the need is more or less than the postulated 5.5 miles? Table 6.2 shows the impacts on costs and benefits for two scenarios: (1) 5.0 miles per 1,000 acres; and (2) 6 miles per 1,000 acres for the "Road, Drainage and Irrigation" investment alternative. Both cases (1) and (2) are still feasible. However, in case (2) the feasibility as measured by the benefit/cost ratio is very marginal.

This test proves the need for inter-disciplinary approach to rural road development. The road infrastructure network should be decided by agriculturist for the crop type to be farmed, and not by traffic volume per se, which determines primarily geometric and structural designs. Project feasibility, and therefore decision to implement, can be significantly affected if the inappropriate network is chosen for rural development.

In Test No. 7, the significance of explicitly accounting for spatial impacts (i.e., population movements) was examined. The impact on rural unemployment is considered for two investment scenarios (i.e., the "Do Nothing" and "Investments in Roads Only"), without explicitly accounting for shifts in population due to relative regional unemployment rates. This was done in the model by holding the Urban In-migration Multiplier at a constant value of zero.

Table 6.2 The Impacts on Costs and Benefits Due to Different Road Infrastructure Need

Tests	Present Value of Costs	Present Value of Benefits	Net Present of Benefits	Benefits/Costs Ratio (B/C)
Base Scenario				
5 1/2 Miles/1000 Acres	41,607,800	55,121,500	13,513,700	1.32
Case 1: 5 Miles/1000 Acres	33,142,200	55,121,500	21,979,300	1.67
Case 2: 6 Miles/1000 Acres	46,307,200	55,121,500	8,814,300	1.19

Table 6.3 shows the impacts on rural unemployment for the two scenarios. In the case of the "Do Nothing" strategy, rural unemployment progressively increases from 43 percent in the year 1995 to 46 percent in the year 2015. In the case of the "Roads Only" investment alternative (assuming normal population movement is going on as expected in any country, and the transportation planner neglected to account for the typical population

movement), rural unemployment drops from 22 percent in the year 1995 (because of the investment) to a low of 2 percent in the year 1999, and then rises to 26 percent in the year 2015.

Table 6.3 The Impacts on Rural Unemployment Rate Due to Lack of Consideration of Inter-Regional Migration

Year	Policies	
	Do-Nothing Unemployment Rate (%)	Roads Only Unemployment Rate (%)
1995	43	22
1996	44	14
1997	44	5
1998	45	3
1999	45	2
2000	45	2
2001	45	3
2002	44	4
2003	43	6
2004	44	7
2005	42	9
2006	43	11
2007	43	12
2008	42	14
2009	42	16
2010	42	18
2011	43	19
2012	43	21
2013	44	23
2014	45	24
2015	46	26

These unemployment characteristics would not occur in a region that has "freedom of movement" (i.e., people will react to the perceived job opportunities in the different parts of the country). Also, in- and out-migration would tend to equalize the regional

unemployment rates and curtail further movement. Furthermore, empirical evidence does attest to the above fact through the rapid growth rates of urban regions -- usually the main generators of new jobs.

The above tests point quite conclusively to the need for the explicit incorporation and analyses of the main socio-economic factors in a model that purports to deal with economic growth. Tests 1 through 5 show that an implicit assumption of the availability of drainage irrigation, mechanization, fertilizer and trucking fleet can seriously overstate the impacts of investments in roads if these key resources are limited or not available. Test 7 reinforces the need for explicit consideration of spatial impacts, since the rural demographic (as measured by unemployment rate) and economic (as measured by income per capita) characteristics would be misleading without any explicit accounting of population movement. Finally, Test 6 indicates the need for appropriate advice on the network characteristics (layout) to be constructed, since both financial and economic feasibilities strongly depend on the choice of the desired road needs.

The following factors (variables) and their impacts on production and productivity are recommended for further pre-and post-project implementation analyses: (a) the response of farmers to increase land development rate, give increased drainage and irrigation, fertilizer, mechanization and technical advice; (b) the migration pattern that depends on job opportunities as measured by the relative regional unemployment characteristics; and (c) the road network characteristics that allow for the optimal exploitation (i.e., accessibility) of new agricultural lands.

Chapter 7

Summary and Conclusions

The basic theme of this thesis has been that the analyses of investment in transportation and related agricultural economic infrastructure in less developed regions of developed countries should be conducted in the light of their won characteristics, needs and objectives. In supports of this point of view, the principal planning methodologies were reviewed, and their limitations and strengths discussed. A conceptual model of the proposed methodology was then developed and applied to a poorly accessible agricultural region in a less developed region -- Chang-Hwa County, Taiwan -- in order to illustrate the characteristics and potentials of the technique.

The following is a summary of the thesis, an indication of its usefulness and possible future research efforts that should be undertaken for the analyses of investments in the economic infrastructure of potentially viable agricultural regions of less developed countries.

7.1 Summary

Chapter 1, by way of introduction, highlighted the role, problems and needs of less developed countries, with respect to transportation as follows.

Transportation is not simply a derived demand of the other socio-economic activities of a region, but a determinant of new production possibilities and the expansion of the economic base of region.

Too often, the expansion of the transport infrastructure has been determined on traffic flows per se, rather than the removal of a developmental bottleneck, to increased production and its concomitant impacts on the region and the nation as a whole.

There is also a widespread, uncoordinated decision making in the transportation planning hierarchy, as evidenced by: (a) the many "ministries" responsible for funding and implementation; and (b) the multimodal transfers required within short distances of travel.

The large allocation of funds (almost 1/3 of the annual gross national income in transportation and related agricultural infrastructure demands an analytical methodology that explicitly incorporates the concerns of other sectors of the economy, if these large investments in transportation are to result in the most beneficial national impacts. System Dynamics Methodology, it is contended, can specifically address the above main problems and needs.

In Chapter 2, the literature search revealed that most of the earlier methodologies used for the evaluation of investments in rural roads are the outcome of work done for scenarios in developed countries where the demand for road (as evidenced by traffic flows) was not really in question. The benefits in these approaches were based primarily on direct road users impacts, resulting from traffic volumes. Where traffic volumes were low, the concept of the benefits from improved accessibility on production and shifts in population was never seriously considered.

In later studies, the limitation of direct road users' costs as the main criterion for economic viability was realized and serious attempts are being made to incorporate the causal impacts of transportation on a region. However, very little has been done so far to

explicitly incorporate feedback behavior and impacts from, and on other sectors of the economy.

Chapter 3 discussed the underlying structure of the proposed methodology and presented the conceptual causal model that defines the impacted region's behavior.

The methodology of system dynamics consists of three distinct phases in the development of a model: (1) conceptual formulation; (2) mathematical simultaneous difference equations; and (3) computer simulation. The conceptual formulation allows for the explicit incorporation of the causality, interrelationships and feedback phenomena that are creating and sustaining the "problem" or "behavior" of the region through the use of di-graphs. The quantification of the system's behavior is undertaken through mathematical model building from available data base or assumed value for a hypothesized behavior where data is lacking. Finally, through the technique of simulation, model calibration and forecasting of future performance are undertaken.

The possible limits or boundary of the impacts of an investment in the economic infrastructure of a typical rural region was identified. The main sectors (demographic, economic and transport) and components (human, natural, and man-made) that "drive" that impacted region's economy were determined.

From a simplified block diagram of the linkages between and among these sectors and components through di-graphs, the complex structure and main feedback phenomena that underlie the behavior of rural investments were developed, discussed and presented as a comprehensive causal model. The comprehensive causal model presented the framework

for data collection and model calibration and use for the evaluation of transport and related investments in rural regions.

The rural region is represented by three sectors: (1) demographic; (2) economic; and (3) transport. The demographic sector, through its two main components of population and housing, provides information (or inputs) on the labor and land consumed by housing. The economic sector is predominantly agricultural and is represented by six components: farmers, drainage, irrigation, arable land, mechanization, and technology (i.e., human, natural and man-made resources). The transport sector is represented by three components: road fund, road miles, and trucks. The dynamic interactions within and among these sectors' components defined the direct impacts.

The urban region is represented by two sectors: demographic and economic, the key sectors that determine the unemployment characteristics of the two regions. Further, the hypothesis of the spatial impacts is due primarily to the relative unemployment characteristics of the two regions; thus the interest is in only these two sectors. The demographic sector is represented by population and housing; the economic sector by businesses and jobs; and the dynamic interactions between their components determine the unemployment characteristics of the urban region. The synthesis of the two regions through their respective unemployment rates results in the development of the comprehensive causal model.

In chapter 4, the data base of Chang-Hwa County, a less developed region, with poorly accessible but potentially viable agricultural regions, is used to calibrate the hypothesized computer model.

Data for the Dro-Shu Coast (referred to as the rural or directly impacted region) and Chang-Hwa City (referred to as the urban or spatially impacted through population movement) were used for model calibration. Where data was lacking, hypotheses of the behavior were made; and from a series of simulation runs and modifications in an iterative manner, the model was accepted as calibrated when the outputs reasonable replicated the basic data of a ten-year period of the region.

Chapter 5 illustrated the characteristics and effectiveness of the methodology for the evaluation of investments in rural economic infrastructure of roads, drainage and irrigation.

The continuum of investment strategies that typifies developing countries is reduced to three main alternatives to development: (1) Do Nothing or continuation of the status quo; (2) Investment in Road infrastructure; and (3) Investment in Roads, Drainage and Irrigation.

The typical road users' benefits of time savings, vehicle operating costs, etc., generally associated with road improvement were not specifically evaluated; but instead, the costs and benefits associated with expansion of the production base and increased production and productivity were the main variables involved in the evaluation of the direct consequences of the investments.

The accepted criteria of benefit/cost ratio and net present value were used to evaluate the direct impacts of the investments. All three investment policies satisfied the above criteria with the "Do Nothing" policy showing the highest benefit/cost ratio, and the comprehensive policy showing the best net present value returns.

In fact, the "Do Nothing" alternative was so competitive that if no other information on the impacts of these alternatives were available, it would indeed be difficult not to accept the "Do Nothing" policy for the next twenty years.

Because of the characteristics of the system dynamics methodology (i.e., a trace of the impacts through time, explicit and quantitative impacts on the key socio-economic indicators of population movements, income per capita, unemployment and timing of the utilization of regional resource), it was realized that the "Do Nothing" strategy resulted in the lowest regional and national impacts. The decreases in rural unemployment and increases in income per capita shown in this alternative were as a result of heavy rural migration. In addition, a rural region with the potential to support not only its existing population but also its natural growing population was lost in its population base; and not until twenty years hence will capitalize on its natural resources.

Whereas, both capital investment strategies alleviated the population outmigration trend in less than ten years and almost greatly increased the gross regional output within ten years for the comprehensive investment policy, resulting in real increases in both rural population and income per capita.

In chapter 6, the use of shadow prices and its limitations, as a "practical tool" for the adjustment of true project costs and benefits, were discussed.

Extensive use was made of the techniques of sensitivity analysis and computer simulation to identify the factors or variables which "drive" the model and determine the socio-economic characteristics of the region.

Sensitivity analyses showed quite conclusively the need for the use of interactive modeling to reflect realistic demographic changes and resource complementarity of investment strategies. Without the linking of the rural and urban regions, unemployment rate rose to approximately 46%. Such a high rural unemployment rate would result in obvious rural outmigration in a real-world scenario, unless, of course, the whole county is suffering from the same degree of unemployment.

Transportation per se was found to be only one of the main resources needed for rural socio-economic expansion and improvements. The implicit assumption of the availability of other key resources (i.e., drainage, irrigation, fertilizer, mechanization, and technology) overstates the impacts of the investments in transportation per se. Sensitivity tests on the availability of other key resources reduced the impacts of transport investment by as much as 65%.

7.2 Conclusions and Recommendation

At first glance, the size and seeming complexity of the proposed model might be questioned for its usefulness for transportation planning, and even more so in less developed region of developing developed countries with obvious resource limitations, for which the model is developed. However, the allocation of large sums of money, in resource scarce economies, in transportation and related economic infrastructures that eventually affect the lives of the present and future generations must of necessity be carefully analyzed if negative impacts are to be minimized.

Planning models that purport to deal with economic growth should provide insights into where the economy is likely to go for a given investment strategy. Such

models should insure consistency, feasibility and a rational determination of priorities. This is not advocating perfection, but only the beginning of an attempt to look at a plan or strategy into and to evaluate projects within this context.

The current approaches tend to deal with the investment in transportation within the limited context of direct users impacts. Even in methodologies where extensions on the direct users impacts are considered, there are no explicit incorporations of the interrelationships and feedback phenomena that underlie the behavior of the economic system. That these complex interrelationships and feedback phenomena exist is verified by empirical evidence; and if we are to improve our ability to make shrewd investment decisions, attempts must be made to understand these complex interrelationships.

The methodology of system dynamics offers an opportunity for the quantitative analyses of these complex interrelationships and feedback phenomena that determine regional performance. The data base needed for model development and calibration might not be as formidable or unavailable as might be first thought. It is very likely that the basic data for preliminary model development already exists in the country in different ministries and organizations. What may be required is the processing of the data into an appropriate information base to develop a crudely calibrated model. Then through the use of computer simulation and sensitivity analyses (characteristics of the methodology) an appropriate data base can be developed; thus avoiding the collection of large volumes of data and the development of statistical regression models that might not be pertinent to the analyses (as may be the case with some traditional transportation planning approaches).

Probably of equal importance too is that the effectiveness or usefulness of the developed model does not end with the project analyses and final recommendations, since the output from the model is a trace of the performance of the economy through time; and also because there are explicit incorporations of the other sectors of the economy, the model can be used to study post-project performance. If forecasted values are not realized, timely adjustment can be made to key resources to correct unwanted impacts.

The last step in the analytical procedure is to narrow the range of choice and finally to present a leading alternative program to the political authorities for decision. Alternative 3 -- the investment in Roads, Drainage and Irrigation -- provides the "best" positive impacts, and it is in keeping with Chang-Hwa County's stated objective of expanding the agricultural base and improving the rural income per capita. It is, therefore recommended that the "comprehensive" policy of investments in Roads, Drainage and Irrigation be implemented for the Dro-Shu Coast. This strategy requires a capital investment of \$23,916,265 in road construction and maintenance over twenty years. The expected net present worth at 10 percent interest rate for this strategy is approximately \$23,233,390 over a twenty-year period, and should sustain a rural population of approximately 42,100 persons at an average income per capita of \$3,725 annually, and greatly decreased urban immigration after year 2000.

7.3 Future Research

Updating the State of the Art

During the preparation of this thesis, it became clear that the preparation of a text of the main methodologies and techniques used in case studies in this subject area would

be of immense benefit to transportation planners in less-developed regions of developing countries.

Significant strides, beyond the concept of direct users impacts, have been made through such planning approaches as producers surplus, linear programming, input/output, interactive structural model (digraphs), cost effectiveness and system dynamics. Moreover, other techniques which are of equal significance, such as micro-analyses by demographers, geographers, agriculturists and engineers in such areas as urban migration, housing, technology and transportation impacts in rural scenarios of developing countries, have been undertaken. However, these works are strewn over a wide range of specialized discipline publications and are at best difficult to come by.

This situation may have resulted because over the past thirty years, the approaches to the analyses of investment in rural economic infrastructure were more or less project-by-project oriented, with specialists looking at their own specific problems (i.e., rural housing, transport, agriculture, etc.). However, the situation is quite different now, since it is felt that (a) the concept of a rural development plan rather than individual project financing (road, drainage, irrigation, housing, etc.), is generally more favored by the financing agencies; and (b) over the past thirty years, a significant amount of work has been done to make such a text feasible.

A guide-line for such a work would be as follows. For each methodology, the items to be produced are:

- Description
- Data Base Requirement

- Probable Time and Cost
- Usefulness of Output Beyond Project Implementation
- Most Likely Scenario for Use
- A Simplified Example

Such a contribution, it is felt, would not only update the state of the art in this area; but would positively reduce pre-feasibility costs and time for actual project implementation, since the needs of an anticipated model would be more or less known.

Model Extension

The study addressed the impacts due to the removal of the bottlenecks (transportation, drainage and irrigation) to agricultural expansion on primarily production, income per capita and migration. However, the impact of agricultural expansion per se is felt beyond the above factors. Typically, the farm sector provides trading, public and private investment resources, and labor to the more rapidly expanding sectors of the economy, as well as increased supply of food and raw materials to support a growing urban population and manufacturing sector. Thus, the strategy for agricultural development (in which transportation plays a key role) should be efficient in a broad sense as follows (Johnston, 1972):

- Achieving a satisfactory rate of increases in farm outputs at a minimum cost by encouraging sequences of innovations which exploit the possibilities for technical change most appropriate to the country's factor endowment.
- Achieving a broadly based improvement in the welfare of the rural population.

- Contributing to the overall rate of national economic growth and process of structural transformation.

A planning procedure that can assess the total efficiency of alternative rural investment strategies would be most useful. The concept of total efficiency is both difficult to define and to analyze; however, this is the problem, and it must be faced if maximization of investment funds is to be realized. It is contended that the system dynamics methodology and the model developed have the flexibility to incorporate other possible impacts due to the increased income from agricultural outputs. Of course, this would require a multi-disciplinary team since specific information on the percent of the increased income that is reinvested at national or regional levels would be needed.

A conceptual causal formulation of the possible linkages between the agricultural sector's increased earnings and the urban manufacturing or business sector is presented in Figure 7.1. The figure is an obvious simplification of the national economy in terms of investment strategies. The concept is that gross national income is obtained from two main sectors (i.e., the urban or industrialized sector, and the rural or farm sector), and it is in turn reinvested in these two sectors. The intent is to illustrate the positive impacts of increased farm income on national growth rate and improved rural standard of living through loops 1 and 2. Loop 1 (Gross Regional Income GRI, Rural Investment Strategies RIS, Rural Infrastructure Growth Rate RIGR, Rural Infrastructure RI, Acreage Cultivated AC, Income From Farming IFF, Regional Income From Farming RIFF) is a positive feedback loop indicating that the expansion of the national agricultural base benefits not only the rural region, but the nation as a whole by providing the capital input to the Urban

Sector. Loop 2 (Rural Income Per Capita RIPC, Rural Migration RM, Rural Population RPOP) is a negative feedback loop indication the impact of rural income on population movements (i.e., the expansion of the farm sector positively impacts rural income (a measure of standard of living), which in turn negatively impacts rural migration, thereby reducing unwanted urban growth).

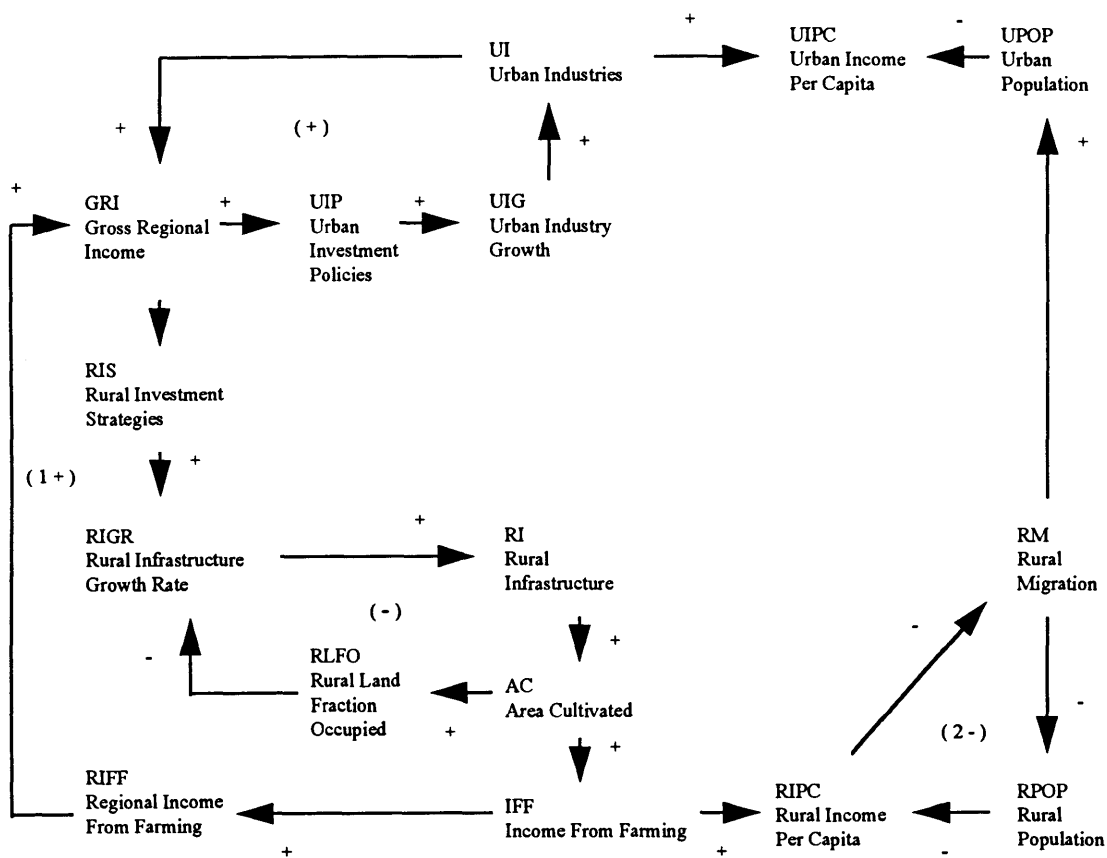


Figure 7.1 Extensive of Impacts of Rural Investment Strategy

In summary, ad hoc and/or piecemeal approach to transportation planning, using essentially non-interactive and feedback methodologies, have resulted in serious under-development or exploitation of the agricultural potentials OF developing countries. And,

agriculture is undoubtedly the mainstay of most less developed regions' economies, and the real national growth rates of the majority of these regions and countries were highly correlated with their agricultural growth rates (i.e., "high-growth" developing countries, as measured by income per capita, were those that had a "high growth" in their agricultural sectors). Even if the perfect set of policies cannot be formulated and implemented, it is hoped that the methodology presented in this study, which is an attempt to explicitly incorporate the linkages and feedbacks that exist between investments in rural economic infrastructure and overall national impacts, would improve the decision-making process and maximize the allocation of scarce resources in developing countries.

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Appendix 1

List of STELLA II Equations

In the following of this paragraph are modeling equations transformed from STELLA (Structural Thinking, Experiential Learning Laboratory with Animation) II software. L, R, A, C, and G, denote as level variable, rate variable, auxiliary variable, constant, and graph function, respectively. Variables' name and definition can be referred in Appendix 2.

```
L      APJ(t) = APJ(t - dt) + (APJGR) * dt
      INIT APJ = 600
R      INFLOWS:
      APJGR = APJGRN*APJ
L      AT(t) = AT(t - dt) + (ATT - ATL) * dt
      INIT AT = 100
R      INFLOWS:
      ATT = (AT*ATTN)/TRT
R      OUTFLOWS:
      ATL = AT*ATLN
L      CHBS(t) = CHBS(t - dt) + (CHBSC - CHBSD) * dt
      INIT CHBS = 50
R      INFLOWS:
      CHBSC = CHBS*CHBSCN*ULFAM*CHCLAM
R      OUTFLOWS:
R      CHBSD = CHBS*CHBSDN
L      CHH(t) = CHH(t - dt) + (CHHC - CHHDR) * dt
      INIT CHH = 20000
R      INFLOWS:
      CHHC = CHH*CHHCN*UHAM*CHCLAM
R      OUTFLOWS:
      CHHDR = CHH*CHHDRN
L      CHMS(t) = CHMS(t - dt) + (CHMSC - CHMSD) * dt
      INIT CHMS = 20
R      INFLOWS:
      CHMSC = CHMS*CHMSCN*CHMLAM*ULFAM
R      OUTFLOWS:
      CHMSD = CHMS*CHMSDN
L      CHPOP(t) = CHPOP(t - dt) + (CHBR + CHI - CHDR - CHO) * dt
      INIT CHPOP = 199800
R      INFLOWS:
      CHBR = CHPOP*CHBRN
      CHI = (UI*(1-CHCLO))/((1-CHCLO)+(1-NBCLO)+(1-WCCLO))
R      OUTFLOWS:
      CHDR = CHPOP*CHDRN
      CHO = CHPOP*CHON
L      CHSS(t) = CHSS(t - dt) + (CHSSC - CHSSD) * dt
      INIT CHSS = 500
R      INFLOWS:
      CHSSC = CHSS*CHSSCN*CHCLAM*ULFAM
R      OUTFLOWS:
      CHSSD = CHSS*CHSSDN
```

```

L   EROAD(t) = EROAD(t - dt) + (RCR - RRDR) * dt
    INIT EROAD = 140
R   INFLOWS:
    RCR = ((MIN(DFR,RCB/CCPM))*IFFM*RRLAM/RCT)*0.25
R   OUTFLOWS:
    RRDR = EROAD/(ARUL*RMM*TTM)
L   HV(t) = HV(t - dt) + (HVPR - HVDR) * dt
    INIT HV = 30
R   INFLOWS:
    HVPR = MAX((RL/LPHV)-HV,0)/HAT
R   OUTFLOWS:
    HVDR = HV*HVDRN
L   IWA(t) = IWA(t - dt) + (IWAR) * dt
    INIT IWA = 156000
R   INFLOWS:
    IWAR = 0
L   NBBS(t) = NBBS(t - dt) + (NBBS - NBBSD) * dt
    INIT NBBS = 50
R   INFLOWS:
    NBBS = NBBS*NBBSCN*ULFAM*NBCLAM
R   OUTFLOWS:
    NBBSD = NBBS*NBBSDN
L   NBEET(t) = NBEET(t - dt) + (NBEETG) * dt
    INIT NBEET = 3500
R   INFLOWS:
    NBEETG = NBEET*NBEETGN
L   NBEIT(t) = NBEIT(t - dt) + (NBEITG) * dt
    INIT NBEIT = 1500
R   INFLOWS:
    NBEITG = NBEIT*NBEITGN
L   NBH(t) = NBH(t - dt) + (NBHC - NBHDR) * dt
    INIT NBH = 4000
R   INFLOWS:
    NBHC = NBH*NBHCN*UHAM*NBCLAM
R   OUTFLOWS:
    NBHDR = NBH*NBHDRN
L   NBMS(t) = NBMS(t - dt) + (NBMSC - NBMSD) * dt
    INIT NBMS = 10
R   INFLOWS:
    NBMSC = NBMS*NBMSCN*NBMLAM*ULFAM
R   OUTFLOWS:
    NBMSD = NBMS*NBMSDN
L   NBPOP(t) = NBPOP(t - dt) + (NBBR + NBI - NBDR) * dt
    INIT NBPOP = 36600
R   INFLOWS:
    NBBR = NBPOP*NBBRN
    NBI = (UI*(1-NBCLO))/((1-NBCLO)+(1-WCCLO)+(1-CHCLO))
R   OUTFLOWS:
    NBDR = NBPOP*NBDRN
L   NBSL(t) = NBSL(t - dt) + (NBSLG - NBSLC) * dt
    INIT NBSL = 42000
R   INFLOWS:
    NBSLG = NBSL*NBSLGN*NBLAM*ULFAM
R   OUTFLOWS:
    NBSLC = NBSL*NBSLCN
L   NBSMI(t) = NBSMI(t - dt) + (NBSMIG) * dt
    INIT NBSMI = 1
R   INFLOWS:
    NBSMIG = NBSMI*NBSMIGN
L   NBSS(t) = NBSS(t - dt) + (NBSSC - NBSSD) * dt
    INIT NBSS = 100
R   INFLOWS:
    NBSSC = NBSS*NBSSCN*NBCLAM*ULFAM
R   OUTFLOWS:
    NBSSD = NBSS*NBSSDN
L   NBTRT(t) = NBTRT(t - dt) + (NBTRTG) * dt
    INIT NBTRT = 1000
R   INFLOWS:
    NBTRTG = NBTRT*NBTRTGN

```

```

L      RF(t) = RF(t - dt) + (RFR - RER) * dt
      INIT RF = 1000000
R      INFLOWS:
      RFR = RF*RFRN
R      OUTFLOWS:
      RER = RCE+RME
L      RFMR(t) = RFMR(t - dt) + (NF - FLR) * dt
      INIT RFMR = 3000
R      INFLOWS:
      NF = DNF*RURM
R      OUTFLOWS:
      FLR = RFMR*FLN*FLM
L      RH(t) = RH(t - dt) + (RHC - RHD) * dt
      INIT RH = 3000
R      INFLOWS:
      RHC = RH*RHCN*RHCM
R      OUTFLOWS:
      RHD = RH*RHDN
L      RL(t) = RL(t - dt) + (RLDR - RLCR) * dt
      INIT RL = 30000
R      INFLOWS:
      RLDR = (MAX(RLDM*RLA*(RAMLD-RLFO),0)/DILD)*2.5
R      OUTFLOWS:
      RLCR = RL*RLCRN*RLCM
L      RP(t) = RP(t - dt) + (RBR - RDR - RM) * dt
      INIT RP = 35000
R      INFLOWS:
      RBR = RP*RBRN
R      OUTFLOWS:
      RDR = RP*RDRN
      RM = RP*UIM
L      RROAD(t) = RROAD(t - dt) + (RCR2) * dt
      INIT RROAD = 150
R      INFLOWS:
      RCR2 = RCR
L      SPBS(t) = SPBS(t - dt) + (SPBSC - SPBSD) * dt
      INIT SPBS = 105
R      INFLOWS:
      SPBSC = SPBS*SPBSCN*SPCLAM*ULFAM
R      OUTFLOWS:
      SPBSD = SPBS*SPBSDN
L      SPEET(t) = SPEET(t - dt) + (SPEETG) * dt
      INIT SPEET = 1500
R      INFLOWS:
      SPEETG = SPEET*SPEETGN
L      SPEIT(t) = SPEIT(t - dt) + (SPEITG) * dt
      INIT SPEIT = 2000
R      INFLOWS:
      SPEITG = SPEIT*SPEITGN
L      SPH(t) = SPH(t - dt) + (SPHC - SPHDR) * dt
      INIT SPH = 12500
R      INFLOWS:
      SPHC = SPH*SPHCN*UHAM*SPCLAM
R      OUTFLOWS:
      SPHDR = SPH*SPHDRN
L      SPOCL(t) = SPOCL(t - dt) + (SPOCLG) * dt
      INIT SPOCL = 2000
R      INFLOWS:
      SPOCLG = SPOCL*SPOCLGN
L      SPPOP(t) = SPPOP(t - dt) + (SPBR - SPDR) * dt
      INIT SPPOP = 82250
R      INFLOWS:
      SPBR = SPPOP*SPBRN
R      OUTFLOWS:
      SPDR = SPPOP*SPDRN
L      SPRL(t) = SPRL(t - dt) + (SPRLG) * dt
      INIT SPRL = 85000
R      INFLOWS:
      SPRLG = SPRL*SPRLGN

```

```

L   SPSL(t) = SPSL(t - dt) + (SPSLG - SPSLC) * dt
    INIT SPSL = 20500
R   INFLOWS:
    SPSLG = SPSL*SPSLGN*SPLAM*ULFAM
R   OUTFLOWS:
    SPSLC = SPSL*SPSLCN
L   SPSMI(t) = SPSMI(t - dt) + (SPSMIG) * dt
    INIT SPSMI = 4
R   INFLOWS:
    SPSMIG = SPSMI*SPSMIGN
L   SPSS(t) = SPSS(t - dt) + (SPSSC - SPSSD) * dt
    INIT SPSS = 85
R   INFLOWS:
    SPSSC = SPSS*SPSSCN*SPCLAM*ULFAM
R   OUTFLOWS:
    SPSSD = SPSS*SPSSDN
L   SPTRT(t) = SPTRT(t - dt) + (SPTRTG) * dt
    INIT SPTRT = 500
R   INFLOWS:
    SPTRTG = SPTRT*SPTRTGN
L   TR(t) = TR(t - dt) + (TRPR - TRDR) * dt
    INIT TR = 300
R   INFLOWS:
    TRPR = MAX((RL/LPTR)-TR,0)
R   OUTFLOWS:
    TRDR = TR*TRDRN
L   TRUCK(t) = TRUCK(t - dt) + (TPR - TDR) * dt
    INIT TRUCK = 20
R   INFLOWS:
    TPR = MAX(DNT-TRUCK,0)/DIP
R   OUTFLOWS:
    TDR = TRUCK*TDRM*TDN
L   UMR(t) = UMR(t - dt) + (UMRPR - UMRTR) * dt
    INIT UMR = 0
R   INFLOWS:
    UMRPR = (YPA1*MIN(RL,RL1)+(IF RL>RL1 OR RL=RL1 THEN YPA2 ELSE 0)*(RL-RL1))
R   OUTFLOWS:
    UMRTR = MIN(RTC,UMRPR)
L   VIS(t) = VIS(t - dt) + (VPR - VDSER) * dt
    INIT VIS = 6
R   INFLOWS:
    VPR = MAX(DNV-VIS,0)/VAT
R   OUTFLOWS:
    VDSER = VIS*VDSERN
L   WCBS(t) = WCBS(t - dt) + (WCBSC - WCBSD) * dt
    INIT WCBS = 150
R   INFLOWS:
    WCBSC = WCBS*WCBSCN*WCCLAM*ULFAM
R   OUTFLOWS:
    WCBSD = WCBS*WCBSDN
L   WCEET(t) = WCEET(t - dt) + (WCEETG) * dt
    INIT WCEET = 3500
R   INFLOWS:
    WCEETG = WCEET*WCEETGN
L   WCEIT(t) = WCEIT(t - dt) + (WCEITG) * dt
    INIT WCEIT = 1500
R   INFLOWS:
    WCEITG = WCEIT*WCEITGN
L   WCH(t) = WCH(t - dt) + (WCHC - WCHDR) * dt
    INIT WCH = 9000
R   INFLOWS:
    WCHC = WCH*WCHCN*UHAM*WCCLAM
R   OUTFLOWS:
    WCHDR = WCH*WCHDRN
L   WCOCL(t) = WCOCL(t - dt) + (WCOCLG) * dt
    INIT WCOCL = 1000
R   INFLOWS:
    WCOCLG = WCOCL*WCOCLGN
L   WCP(t) = WCP(t - dt) + (WCBR + WCI - WCDR) * dt

```

```

INIT WCPop = 78250
R INFLOWS:
WCBR = WCPop*WCBRN
WCI = (UI*(1-WCCLO))/((1-WCCLO)+(1-NBCLO)+(1-CHCLO))
R OUTFLOWS:
WCDR = WCPop*WCDRN
L WCSL(t) = WCSL(t - dt) + (WCSLG - WCSLC) * dt
INIT WCSL = 65000
R INFLOWS:
WCSLG = WCSL*WCSLGN*WCLAM*ULFAM
R OUTFLOWS:
WCSLC = WCSL*WCSLCN
L WCSMI(t) = WCSMI(t - dt) + (WCSMIG) * dt
INIT WCSMI = 2
R INFLOWS:
WCSMIG = WCSMI*WCSMIGN
L WCSS(t) = WCSS(t - dt) + (WCSSC - WCSSD) * dt
INIT WCSS = 180
R INFLOWS:
WCSSC = WCSS*WCSSCN*WCLAM*ULFAM
R OUTFLOWS:
WCSSD = WCSS*WCSSDN
L WCTRT(t) = WCTRT(t - dt) + (ECTRTG) * dt
INIT WCTRT = 1000
R INFLOWS:
ECTRTG = WCTRT*WCTRTGN
A AJ = RL*JPA
C ANI = 1000
C ANP = 20
C AO = 3
C APF = 8
C APJGRN = 0.06
A APPF = PPA*APF
A ARD = RRoad/RLA
C AROW = 10
C ARUL = 10
C ATD = 100
C ATLN = 0.05
A ATPR = ATD/(AVS*24)
A ATTFR = ((AT*RFAT)/RFMR)
C ATTN = 0.25
C AVS = 7
C AWHD = 10
C BE = 5
C BO = 20
C CCPM = 100000
C CF = 0.5
A CFA = NRCA+NLDA+NMICA+(FI*COF)+(FCOT*YPAM)+WTCT
C CHBRN = 0.0318
C CHBSCN = 0.03
C CHBSDN = 0.001
C CHCLAN = 5000
A CHCLO = (CHH*CHLPH+CHBS*CHLPBS+CHSS+CHLPSS)/CHCLAN
C CHDRN = 0.0126
C CHHCN = 0.01
C CHHDRN = 0.001
A CHJ = CHBS*JPGBS+CHSS*JPGSS+CHMS*JPGMS
A CHLF = CHPOP*LFPR
C CHLPBS = 10
C CHLPH = 0.1
C CHLPM = 600
C CHLPSS = 2
C CHMLA = 13220
A CHMLFO = (CHMS*CHLPM)/CHMLA
C CHMSCN = 0.03
C CHMSDN = 0.001
C CHON = 0.005
C CHSSCN = 0.03
C CHSSDN = 0.001
A CHUR = ((CHLF-CHJ)/CHLF)*100

```

A CHURRUR = (CHUR/100)/RUR
C COF = 0.2
C DADT = 100
C DCPD = 200
A DFR = DRM-RROAD
C DIAM2 = 1
C DILD = 5
C DIP = 2
C DLPF = 25
A DNF = MAX(RAMLD-RLFO,0)*RLA/DLPF
A DNT = UMRPR/(TTPD*PLPT*HPP)
A DNV = QTW/(TPV*PLPV)
C DRD = 0.0055
A DRM = DRD*RLA
C EPPA = 100
A ERD = EROAD/RLA
A ETARR = EROAD/RROAD
A ETT = (IGED/ANP)*ERDM
A FCOT = FTCN*ARTCM
A FI = FN+(FTCN-FCOT)/COF
C FLN = 0.01
A LTR = (RFMR*DLPF)/RL
C FN = 100
A FPFC = DFRM+ETARM
C FTCN = 10
A FTLR = (RFMR*DLPF)/RL
A FTNIR = APPF/ANI
C HAT = 2
C HPP = 60
C HVDRN = 0.1
C IGED = 16
A JFRCM = (RCR*20)+(RROAD*2)
C JPA = 0.3
C JPBS = 30
C JGBS = 30
C JGMS = 300
C JGSS = 100
C JPNBMS = 100
C JPNBSMI = 2000
C JPOCL = 0.5
C JPRL = 0.3
C JPSS = 0.15
C JSPBS = 10
C JPSPSMI = 1000
C JPSS = 20
C JPWCBS = 10
C JPWCOCL = 0.3
C JPWCSMI = 1000
C LFPP = 0.4
C LFPR = 0.4
C LPBS = 5
C LPH = 0.25
C LPHV = 1000
C LPNBMS = 600
C LPRH = 0.5
C LPSMI = 500
C LPSS = 5
C LPTR = 100
C MCPM = 5000
A MFPM = RMB/RROAD
A MIM = RLHRM*RLTRM
A NBADT = ((NBEIT+NBEET+NBIET)*PA)/AO+(((NBIET+NBEET+NBEIT)*PB)/BO)*BE+(NBTRT*TE)
C NBARN = 0.0318
C NBBSN = 0.05
C NBBSDN = 0.001
A NBCLA = NBCLAN+NBSLC
C NBCLAN = 18000
A NBCLO = (NBH*LPH+NBBS*LPBS+NBSS*LPSS)/NBCLA
C NBDRN = 0.0126
C NBEETGN = 0.03

C NBEITGN = 0.03
C NBHCN = 0.02
C NBHDRN = 0.015
A NBIENWT = NBPOP*TPP
A NBIET = NBIEWT+NBIENWT
A NBIEWT = ((NBUR*UFCHJ)/(NBUR+WCUR+SPUR))*TPJ
A NBJ = NBSMI*JPNBSMI+NBBS*JPBS+NBSS*JPSS+NBMS*JPNBMS+NBSL*JPSL+APJ
C NBLA = 48000
A NBLF = NBPOP*LFPR
A NBLFO = (NBH*LPH+NBSMI*LPSMI+NBBS*LPBS+NBSS*LPSS+NBSL)/NBLA
C NBMLA = 52000
A NBMLFO = (NBMS*LPNBMS)/NBMLA
C NBMSCN = 0.001
C NBMSDN = 0.0001
A NBPHF = NBADT*PPH
C NBSLCN = 0.002
C NBSLGN = 0.03
C NBSMIGN = 0.03
C NBSSCN = 0.03
C NBSSDN = 0.001
C NBTRTGN = 0.03
A NBUR = ((NBLF-NBJ)/NBLF)*100
C NLDA = 75
C NMICA = 100
C NPH = 10
C NRCA = 15
C NUR = 0.16
C OFLC = 0.2
C OFLT = 0.5
C ONLC = 0.2
C ONLT = 1
C PA = 0.8
C PB = 0.2
C PH = 6
C PHP = 100
C PLPT = 7
C PLPV = 300
A PPA = (YPA1*SPT)-CFA
C PPH = 0.15
A QDCT = (DCPD/PLPV)*QDM
A QTW = RFD*RTWCR
C RBRN = 0.028
A RCB = RF*FPFC
A RCE = MIN(RCB,RCR*CCPM)
C RCPC = 0.1
C RCT = 5
C RDLA = 10000
A RDLFO = (RROAD*AROW)/RDLA
C RDRN = 0.006
C RFAT = 0.05
A RFD = (UMRPR*CF)-RP*RCPC
C RFRN = 0.4
C RHCN = 0.017
C RHDN = 0.01
A RHHR = RP/(RH*NPH)
C RL1 = 30000
C RLA = 60000
C RLCRN = 0.001
A RLDM = ALAM*FAM*MIM*PFRM*DIAM1
A RLF = RP*RPPF
A RLFO = (RROAD*AROW+RH*LPRH+RL)/RLA
A RLHR = RL/(HV*LPHV)
A RLTR = RL/(TR*LPTR)
A RLTWR = (RL*WRPA)/IWA
A RMB = RF*(1-FPFC)
A RME = MIN(RMB,RROAD*MCPM)
C RPPF = 0.45
A RTC = TRUCK*TPPD*HPP*PLPT
C RTCN = 100
A RTMC = RTCN

A RUR = (RLF-(AJ+JFRM))/RLF
A SPADT = ((SPEIT+SPEET+SPIET)*PA)/AO+(((SPIET+SPEET+SPEIT)*PB)/BO)*BE+(SPTRT*TE)
C SPBRN = 0.0318
C SPBSCN = 0.015
C SPBSDN = 0.001
A SPCLA = SPCLAN+SPSLC
C SPCLAN = 27000
A SPCLO = (SPH*LPH+SPBS*LPBS+SPSS*LPSS)/SPCLA
C SPDRN = 0.0126
C SPEETGN = 0.03
C SPEITGN = 0.03
C SPHCN = 0.02
C SPHDRN = 0.015
A SPIENWT = SPOPOP*TPP
A SPIET = SPIEWT+SPIENWT
A PIEWT = ((SPUR*UFCHJ)/(SPUR+NBUR+WCUR))*TPJ
A SPJ = SPSMI*JPSPSMI+SPBS*JPSPBS+SPSS*JPSS+SPSL*JPST+SPOCL*JPOCL+SPRL*JPRL
C SPLA = 70000
A SPLF = SPOPOP*LFPR
A SPLFO = (SPH*LPH+SPOCL+SPSMI*LPSMI+SPBS*LPBS+SPSS*LPSS+SPSL+SPRL)/SPLA
C SPOCLGN = 0.01
A SPPHF = SPADT*PPH
C SPRLGN = 0.03
C SPSLCN = 0.002
C SPSLGN = 0.03
C SPSMIGN = 0.001
C SPSSCN = 0.015
C SPSSDN = 0.001
C SPT = 200
C SPTRTGN = 0.03
A SPUR = ((SPLF-SPJ)/SPLF)*100
C TDN = 0.1
C TE = 3
C TPJ = 3
C TPP = 0.2
A TPV = PHP/((ONLT+OFLT)+ATPR*QDM)
C TRDRN = 0.1
C TRT = 4
A TT = (UMRTR/PLPT)*2
A TTC = (ATPR*VCPD)/PLPV
A TTPD = AWHD/ETT
A UFCHJ = CHJ-((1-UUR/100)*CHLF)
A UH = CHH+NBH+WCH+SPH
A UHHR = UPOP/(UH*PH)
A UI = UPOP*UIN+CHPOP*CHON+UIM*RP
C UIN = 0.009
A UJ = CHJ+NBH+WCH+SPJ
A ULF = UPOP*LFPP
A ULFTJR = ULF/UJ
A UPOP = CHPOP+NBPOP+WCPOP+SPPOP
A UUR = ((ULF-UJ)/ULF)*100
C VAT = 3
C VCPD = 1000
C VDSERN = 0.025
A WCADT = ((WCEIT+WCEET+WCIET)*PA)/AO+(((WCIET+WCEET+WCEIT)*PB)/BO)*BE+(WCTRTR*TE)
C WCBRN = 0.0318
C WCBSCN = 0.015
C WCBSDN = 0.001
A WCCLA = WCCLAN+WCSLC
C WCCLAN = 25000
A WCCLO = (WCH*LPH+WCBS*LPBS+WCSS*LPSS)/WCCLA
C WCDRN = 0.0126
C WCEETGN = 0.03
C WCEITGN = 0.03
C WCHCN = 0.02
C WCHDRN = 0.015
A WCIENWT = WCPOP*TPP
A WCIET = WCIEWT+WCIENWT
A WCIEWT = ((WCUR*UFCHJ)/(WCUR+NBUR+SPUR))*TPJ

A WCJ = WCSMI*JPWCMSI+WCBS*JPWCBS+WCSS*JPSS+WCSL*JPSL+WCOCL*JPWCOCL
C WCLA = 70000
A WCLF = WCPop*LFPF
A WCLFO = (WCH*LPH+WCOCL+WCSMI*LPSMI+WCBS*LPBS+WCSS*LPSS+WCSL)/WCLA
C WCOCLGN = 0.03
A WCPHF = WCADT*PPH
C WCSLCN = 0.002
C WCSLGN = 0.03
C WCSMIGN = 0.001
C WCSSCN = 0.015
C WCSSDN = 0.001
C WCTRTGN = 0.03
A WCUR = ((WCLF-WCJ)/WCLF)*100
C WRPA = 5.2
A WTCPR = TPV*VIS*PLPV
A WTCT = (ONLC+OFLC+TTC+QDCT)
A WTR = MIN(WTCPR,QTW)
A YPA1 = YPAN*FEAM*DIAM1*MIM*HM
A YPA2 = YPAN*FEAM*DIAM2*MIM*HM
A YPAM = FEAM*DIAM2*MIM*HM
A YPAN = 0.6
G ALAM = GRAPH(RLFO)
(0.0, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)
G ARTCM = GRAPH(ARD/DRD)
(0.00, 1.50), (0.1, 1.45), (0.2, 1.40), (0.3, 1.35), (0.4, 1.30), (0.5, 1.20), (0.6, 1.10), (0.7, 1.00), (0.8, 0.9), (0.9, 0.85),
(1.00, 0.8)
G CHCLAM = GRAPH(CHCLO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.75), (0.9, 0.5),
(1.00, 0.00)
G CHMLAM = GRAPH(CHMLFO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)
G DFRM = GRAPH(ARD/DRD)
(0.00, 1.00), (0.1, 0.95), (0.2, 0.9), (0.3, 0.9), (0.4, 0.85), (0.5, 0.75), (0.6, 0.7), (0.7, 0.6), (0.8, 0.5), (0.9, 0.2), (1.00, 0.00)
G DIAM1 = GRAPH(RLTWR)
(0.00, 2.00), (0.2, 1.95), (0.4, 1.90), (0.6, 1.85), (0.8, 1.80), (1.00, 1.75), (1.20, 1.60), (1.40, 1.60), (1.60, 1.60), (1.80, 1.60),
(2.00, 1.60)
G ERDM = GRAPH(ETARR)
(0.00, 2.00), (0.1, 2.00), (0.2, 2.00), (0.3, 2.00), (0.4, 1.90), (0.5, 1.80), (0.6, 1.70), (0.7, 1.50), (0.8, 1.20), (0.9, 1.10),
(1.00, 1.00)
G ETARM = GRAPH(ETARR)
(0.00, 0.00), (0.1, 0.1), (0.2, 0.2), (0.3, 0.3), (0.4, 0.4), (0.5, 0.5), (0.6, 0.7), (0.7, 0.75), (0.8, 0.9), (0.9, 0.95), (1.00, 1.00)
G FAM = GRAPH(FLTR)
(0.00, 0.2), (0.2, 0.25), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7), (1.00, 1.00), (1.20, 1.35), (1.40, 1.60), (1.60, 1.80), (1.80, 1.95),
(2.00, 2.00)
G FEAM = GRAPH(FI)
(0.00, 1.00), (10.0, 1.05), (20.0, 1.10), (30.0, 1.15), (40.0, 1.20), (50.0, 1.25), (60.0, 1.30), (70.0, 1.35), (80.0, 1.40),
(90.0, 1.45), (100, 1.50), (110, 1.60), (120, 1.70), (130, 1.75)
G FLM = GRAPH(FTNIR)
(0.00, 2.00), (0.2, 1.90), (0.4, 1.80), (0.6, 1.60), (0.8, 1.20), (1.00, 1.00), (1.20, 0.58), (1.40, 0.3), (1.60, 0.2), (1.80, 0.1),
(2.00, 0.00)
G HM = GRAPH(ATTFR)
(0.001, 1.00), (0.0018, 1.04), (0.0026, 1.06), (0.0034, 1.08), (0.0042, 1.09), (0.005, 1.10)
G IFFM = GRAPH(FTLR)
(0.00, 0.2), (0.2, 0.25), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7), (1.00, 1.00), (1.20, 1.35), (1.40, 1.60), (1.60, 1.80), (1.80, 1.95),
(2.00, 2.00)
G NBCLAM = GRAPH(NBCLO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)
G NBLAM = GRAPH(NBLFO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)
G NBMLAM = GRAPH(NBMLFO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)
G PFRM = GRAPH((PPA/EPPA))
(0.00, 0.05), (0.1, 0.1), (0.2, 0.3), (0.3, 0.4), (0.4, 0.6), (0.5, 0.8), (0.6, 1.50), (0.7, 1.60), (0.8, 1.70), (0.9, 1.80), (1.00, 2.00)
G QDM = GRAPH(QDPV)
(0.00, 1.00), (0.25, 1.12), (0.5, 1.25), (0.75, 1.38), (1.00, 1.50), (1.25, 1.62), (1.50, 1.75), (1.75, 1.88), (2.00, 2.00)

G QDPV = GRAPH(VIS)
(1.00, 0.00), (2.00, 0.25), (3.00, 0.5), (4.00, 0.75), (5.00, 1.00), (6.00, 1.25), (7.00, 1.50), (8.00, 1.75), (9.00, 2.00)

G RAMLD = GRAPH(ARD/DRD)
(0.00, 0.00), (0.1, 0.2), (0.2, 0.4), (0.3, 0.5), (0.4, 0.55), (0.5, 0.6), (0.6, 0.65), (0.7, 0.7), (0.8, 0.8), (0.9, 0.9), (1.00, 1.00)

G RHCM = GRAPH(RHHR)
(0.00, 0.2), (0.2, 0.25), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7), (1.00, 1.00), (1.20, 1.35), (1.40, 1.60), (1.60, 1.80), (1.80, 1.95),
(2.00, 2.00)

G RLCM = GRAPH(PPA/EPPA)
(0.00, 2.00), (0.2, 1.95), (0.4, 1.80), (0.6, 1.60), (0.8, 1.35), (1.00, 1.00), (1.20, 0.7), (1.40, 0.5), (1.60, 0.35), (1.80, 0.25),
(2.00, 0.2)

G RLFM = GRAPH(PPA/EPPA)
(0.00, 2.00), (0.2, 1.95), (0.4, 1.80), (0.6, 1.60), (0.8, 1.35), (1.00, 1.00), (1.20, 0.7), (1.40, 0.5), (1.60, 0.35), (1.80, 0.25),
(2.00, 0.2)

G RLHRM = GRAPH(RLHR)
(0.00, 1.00), (0.2, 1.00), (0.4, 1.00), (0.6, 1.00), (0.8, 0.95), (1.00, 0.9), (1.20, 0.8), (1.40, 0.6), (1.60, 0.5)

G RLTRM = GRAPH(RLTR)
(0.00, 1.30), (0.2, 1.20), (0.4, 1.10), (0.6, 1.00), (0.8, 0.95), (1.00, 0.9), (1.20, 0.8), (1.40, 0.6), (1.60, 0.5)

G RMM = GRAPH(MFPM/MCPM)
(0.00, 1.00), (0.2, 1.40), (0.4, 1.65), (0.6, 1.80), (0.8, 1.90), (1.00, 2.00)

G RRLAM = GRAPH(RDLFO)
(0.00, 1.00), (0.2, 1.30), (0.4, 1.45), (0.6, 1.30), (0.8, 0.5), (1.00, 0.00)

G RTWCR = GRAPH(WTCT/RTMC)
(0.5, 1.00), (0.75, 0.9), (1.00, 0.45), (1.25, 0.3), (1.50, 0.1), (1.75, 0.05), (2.00, 0.00)

G RURM = GRAPH(RUR/NUR)
(0.00, 0.1), (0.1, 0.1), (0.2, 0.2), (0.3, 0.5), (0.4, 0.8), (0.5, 1.00), (0.6, 1.20), (0.7, 1.40), (0.8, 1.50), (0.9, 1.80), (1.00, 2.00)

G SPCLAM = GRAPH(SPCLO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)

G SPLAM = GRAPH(SPLFO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)

G TDRM = GRAPH(ETARR)
(0.00, 1.90), (0.1, 1.75), (0.2, 1.70), (0.3, 1.65), (0.4, 1.60), (0.5, 1.55), (0.6, 1.50), (0.7, 1.40), (0.8, 1.20), (0.9, 1.10),
(1.00, 1.00)

G TTM = GRAPH((TT/300)/DADT)
(0.00, 2.00), (0.2, 2.00), (0.4, 1.80), (0.6, 1.60), (0.8, 1.40), (1.00, 1.00), (1.20, 0.9), (1.40, 0.8), (1.60, 0.5), (1.80, 0.3),
(2.00, 0.2)

G UHAM = GRAPH(UHHR)
(0.00, 0.1), (0.2, 0.2), (0.4, 0.35), (0.6, 0.5), (0.8, 0.7), (1.00, 1.00), (1.20, 1.60), (1.40, 1.80), (1.60, 1.90), (1.80, 1.95),
(2.00, 2.00)

G UIM = GRAPH(CHURRUR)
(0.5, 0.04), (0.6, 0.03), (0.7, 0.025), (0.8, 0.01), (0.9, 0.005), (1.00, 0.00), (1.10, -0.005), (1.20, -0.01), (1.30, -0.015),
(1.40, -0.02), (1.50, -0.025), (1.60, -0.025), (1.70, -0.027), (1.80, -0.0275), (1.90, -0.03), (2.00, -0.035)

G ULFAM = GRAPH(ULFTJR)
(0.00, 0.1), (0.2, 0.15), (0.4, 0.2), (0.6, 0.3), (0.8, 0.5), (1.00, 1.00), (1.20, 1.30), (1.40, 1.50), (1.60, 1.70), (1.80, 1.90),
(2.00, 2.00)

G WCCLAM = GRAPH(WCCLO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)

G WCLAM = GRAPH(WCLFO)
(0.00, 1.00), (0.1, 1.15), (0.2, 1.30), (0.3, 1.40), (0.4, 1.50), (0.5, 1.40), (0.6, 1.30), (0.7, 0.9), (0.8, 0.5), (0.9, 0.25),
(1.00, 0.00)

Appendix 2

Definition of Variable Names

AJ	: AGRICULTURAL JOBS (JOBS)
ALAM	: AGRICULTURAL LAND AVAILABILITY MULTIPLIER (DIMENSIONLESS)
ANI	: AVERAGE NATIONAL URBAN INCOME (\$/YEAR)
ANP	: AVERAGE TRAVEL SPEED (MILES/HOUR)
AO	: AUTO EQUIVALENT
APF	: ACRE PER FARMER (ACRE/FARMER)
APPF	: AVERAGE PROFIT PER FARMER (\$/CROP)
ARD	: ACTUAL ROAD DENSITY(FRACTION)
AROW	: AVERAGE RIGHT OF WAY (ACRES/MILE)
ARTCM	: ACTUAL ROAD TRANSPORT COST MULTIPLIER (DIMENSIONLESS)
ARUL	: AVERAGE ROAD USEFUL LIFE (YEARS)
AT	: AGRICULTURAL TECHNICIANS (TECHNICIANS)
ATD	: AVERAGE TRAVEL DISTANCE (MILES)
ATL	: AGRICULTURAL TECHNICIAN LEAVING RATE (TECHNICIANS/YEAR)
ATLN	: AGRICULTURAL TECHNICIAN LEAVING RATE NORMAL (FRACTION)
ATPR	: AVERAGE TIME PER ROUTE (DAYS)
ATT	: AGRICULTURAL TECHNICIAN TRAINING RATE (TECHNICIANS/YEAR)
ATTFR	: AGRICULTURAL TECHNICIANS TO FARMERS RATIO (FRACTION)
ATTN	: AGRICULTURAL TECHNICIAN TRAINING RATE NORMAL (FRACTION)
AVS	: AVERAGE VESSEL SPEED (MILES/HOUR)
AWHD	: AVERAGE WORKING HOURPER DAY (HOURS/DAY)
BE	: BUS EQUIVALENT (PASSENGER CAR UNITS/BUS)
BO	: BUS OCCUPANCY
CCPM	: CONSTRUCTION COST PER MILE (\$/MILE)
CF	: UNMILLED RICE CONVERSION RATIO (FRACTION)
CFA	: COST OF FARMING PER ACRE (\$/ACRE)
CHBR	: CHANG-HWA CITY BIRTH RATE (PEOPLE/YEAR)
CHBRN	: CHANG-HWA CITY BIRTH RATE NORMAL (FRACTION)
CHBS	: CHANG-HWA CITY BUSINESS STRUCTURES (STRUCTURES)
CHBSC	: CHANG-HWA CITY BUSINESS STRUCTURES CONSTRUCTION
CHBSCN	: CHANG-HWA CITY BUSINESS STRUCTURES CONSTRUCTION NORMAL
CHBSD	: CHANG-HWA CITY BUSINESS STRUCTURES DETERIORATION
CHBSKN	: CHANG-HWA CITY BUSINESS STRUCTURES DETERIORATION NORMAL
CHCLAM	: CHANG-HWA CITY CIVIC LAND AVAILABILITY MULTIPLIER
CHCLAN	: CHANG-HWA CITY CIVIC LAND AREA NORMAL (ACRES)
CHCLD	: CHANG-HWA CITY CIVIC LAND FRACTION OCCUPIED (FRACTION)
CHDR	: CHANG-HWA CITY DEATH RATE (PEOPLE/YEAR)
CHDRN	: CHANG-HWA CITY DEATH RATE NORMAL (FRACTION)
CHH	: CHANG-HWA CITY SHOUSES (HOUSES)
CHHC	: CHANG-HWA CITY HOUSING CONSTRUCTION (HOUSES/YEAR)
CHHCN	: CHANG-HWA CITY HOUSING CONSTRUCTION NORMAL (FRACTION)
CHHDR	: CHANG-HWA CITY HOUSING DETERIORATION RATE (HOUSES/YEAR)
CHHDRN	: CHANG-HWA CITY HOUSING DETERIORATION RATE NORMAL (FRACTION)
CHI	: CHANG-HWA CITY INMIGRATION (PEOPLE/YEAR)
CHJ	: CHANG-HWA CITY JOBS (JOBS)
CHLF	: CHANG-HWA CITY LABOR FORCE (PEOPLE)
CHLPBS	: CHANG-HWA CITY LAND PER BUSINESS STRUCTURE (ACRE/BUSINESS)
CHLPH	: CHANG-HWA CITY LAND PER HOUSE (ACRE/HOUSE)
CHLPSS	: CHANG-HWA CITY LAND PER SERVICE STRUCTURE

CHLPM : CHANG-HWA CITY LAND PER MANUFACTURE (FEET)
 CHO : CHANG-HWA CITY OUTMIGRATION (PEOPLE/YEAR)
 CHON : CHANG-HWA CITY OUTMIGRATION NORMAL (FRACTION)
 CHPOP : CHANG-HWA CITY POPULATION (PEOPLE)
 CHSS : CHANG-HWA CITY SERVICE STRUCTURES (STRUCTURES)
 CHSSC : CHANG-HWA CITY SERVICE STRUCTURES CONSTRUCTION
 (STRUCTURES/YEAR)
 CHSSCN : CHANG-HWA CITY SERVICE STRUCTURES CONSTRUCTION NORMAL
 CHSSD : CHANG-HWA CITY SERVICE STRUCTURES DETERIORATION
 CHUR : CHANG-HWA CITY UNEMPLOYMENT RATE (PERCENT)
 CHURRUR : CHANG-HWA CITY TO RURAL UNEMPLOYMENT RATIO (FRACTION)
 CHMLA : CHANG-HWA CITY MANUFACTURE LAND AVAILABLE (FEET)
 CHMLAM : CHANG-HWA CITY MANUFACTURE LAND AVAILABILITY MULTIPLIER
 CHMLFO : CHANG-HWA CITY MANUFACTURE LAND FRACTION OCCUPIED
 (FRACTION)
 CHMS : CHANG-HWA CITY MANUFACTURE STRUCTURES (MANUFACTURES)
 CHMSC : CHANG-HWA CITY MANUFACTURE STRUCTURES CONSTRUCTION
 (MANUFACTURES/YEARS)
 CHMSCN : CHANG-HWA CITY MANUFACTURE STRUCTURES CONSTRUCTION
 NORMAL (FRACTION)
 CHMSD : CHANG-HWA CITY MANUFACTURE STRUCTURES DETERIORATION
 (MANUFACTURES/YEAR)
 CHMSDN : CHANG-HWA CITY MANUFACTURE STRUCTURES DETERIORATION NORMAL
 (FRACTION)
 COF : COST OF FERTILIZER (\$LB)

 DADT : DESIGN AVERAGE DAILY TRAFFIC (TRUCK TRIPS/DAY)
 DCPD : DELAY COST PER DAY (\$/DAY)
 DFR : DEMAND FOR ROADS (MILES)
 DFRM : DEMAND FOR ROAD MULTIPLIER (DIMENSIONLESS)
 DIAM : DRAINAGE AND IRRIGATION MULTIPLIER (DIMENSIONLESS)
 DILD : DELAY IN LAND DEVELOPMENT RATE (YEARS)
 DIP : DELAY IN TRACK PURCHASE TIME (YEARS)
 DLPF : DESIRED LAND PER FARMER (ACRES/FARMER)
 DNF : DESIRED UNMBER OF FARMER (FARMERS)
 DNT : DESIRED NUMBER OF TRUCKS (TRUCKS)
 DNV : DESIRED NUMBER OF VESSELS (VESSELS)
 DRD : DESIRED ROAD DENSITY (FRACTION)
 DRM : DESIRED ROAD MILES (MILES)

 EPPA : EXECTED PROFIT PER ACRE (\$/ACRE)
 ERD : EFFECTIVE ROAD DENSITY (FRACTION)
 ERDM : EFFECTIVE ROAD DENSITY MULTIPLIER (DIMENSIONLESS)
 EROAD : EFFECTIVE ROAD (MILES)
 ETARM : EFFECTIVE TO ACTUAL ROAD MULTIPLIER (DIMENSIONLESS)
 ETARR : EFFECTIVE TO ACTUAL ROAD RATIO (FRACTION)
 ETT : EFFECTIVE TRAVEL TIME (HOURS/TRIP)
 FAM : FARMERS AVAILABILITY MULTIPLIER (DIMENSIONLESS)
 FAMT : FARMERS AVAILABILITY MULTIPLIER GRAPH FUNCTION
 FCOT : FARMING COST OF TRANSPORT (S/ACRE)
 FEAM : FERTILIZER AVAILABILITY MULTIPLIER (DIMENSIONLESS)
 FEAMT : FERTILIZER AVAILABILITY MULTIPLIER GRAPH FUNCTION
 FI : FERTILIZER INPUT (LBS/ACRE)
 FLM : FARMERS LEAVING MULTIPLIER (DIMENSIONLESS)
 FLN : FARMERS LEAVING RATE NORMAL (FRACTION)
 FLR : FARMERS LEAVING RATE (FARMERS/YEAR)
 FN : FERTILIZER INPUT NORMAL (LBS/ACRE)
 FPFC : FRACTIONFOR CONSTRUCTION (FRACTION)
 FTCH : FARMING COST OF TRANSPORT NORMAL (\$/ACRE)

FTLR : FARMERS TO LAND RATIO (FRACTION)
 FTNIR : FARMERS TO NATIONAL URBAN INCOME (RATIO)

HAT : HARVESTER ACQUISITION TIME (YEAR)
 HM : HUSBANDRY MULTIPLIER (DIMENSIONLESS)
 HPP : HARVEST PEAK PERIOD (DAYS)
 HV : HARVESTERS
 HVDR : HARVESTER DEPRECIATION RATE (HARVESTERS/YEAR)
 HVDRN : HARVESTER DEPRECIATION NORMAL (FRACTION)
 HVPR : HARVESTER PURCHASE RATE (HARVESTER/YEAR)

IFFM : INFLUENCE FROM FARMERS MULTIPLIER (DIMENSIONLESS)
 IGED : INITIAL GRID DISTANCE (MILES)
 IWA : IRRIGATION WATER AVAILABLE (ACRE-FEET)

JFRCM : JOBS FROM ROAD CONSTRUCTION (JOBS/MILE OF CONSTRUCTION)
 JPA : JOBS PER ACRE (JOBS/ACRE RICE LAND)
 JPBS : JOBS PER BUSINESS STRUCTURES (JOBS/BUSINESS)
 JPNBSMI : JOBS PER NORTH BANK SUGAR MANUFACTURING INDUSTRY
 JPNBMS : JOBS PER NORTH BANK MANUFACTURE STRUVTURES
 (JOBS/MANUFACTURE)
 JPWCBS : JOBS PER WEST COAST BUSINESS STRUCTURES (JOBS/STRUCTURES)
 JPWCOCL : JOBS PER WEST COAST OTHER CROP LAND (JOBS/ACRE)
 JPWCSMI : JOBS PER WEST COAST SUGAR MANUFACTURING INDUSTRY
 (JOBS/INDUSTRY)
 JPGBS : JOBS PER BUSINESS STRUCTURE (JOBS/BUSINESS)
 JPGSS : JOBS PER SERVICE STRUCTURE (JOBS SERVICE STRUCTURE)
 JPGTMS : JOBS PER SHARF (JOBS/MANUFACTURE)
 JPOCL : JOBS PER OTHER CROP LAND (JOBS/ACRE)
 JPRL : JOBS PER RICE LAND (JOBS/ACRE)
 JPSL : JOBS PER SUGAR LAND (JOBS/ACRE)
 JPSS : JOBS PER SERVICE STRUCTURES (JOBS/SERVICE STRUCTURES)
 JPWCSMI : JOBS PER WEST COAST SUGAR MANUFACTURING INDUSTRY

LFPF : LABOR FORCE PARTICIPATION FRACTION (FRACTION)
 LFPR : LABOR FORCE PARTICIPATION RATE (FRACTION)
 LPBS : LAND PER BUSINESS STRUCTURES (ACRE/BUSINESS)
 LPNBMS : LAND PER NORTH BANK MANUFACTURE STRUCTURES (FEET)
 LPH : LAND PER HOUSE (ACRE/HOUSE)
 LPRH : LAND PER RURAL HOUSE (ACRES/HOUSE)
 LPSMI : LAND PER SUGAR MANUFACTURING INDUSTRY (ACRES/SUGARINDUSTRY)
 LPSS : LAND PER SERVICE STRUCTURES(ACRES/SERVICE STRUCTURES)
 LPTR : LAND PER TRACTOR (ACRES)

MCPM : MAINTENANCE COST PER MILE (\$/MILE)
 MFPM : MAINTENANCE FUND PER MILE (\$/MILE)
 MIM : MECHANIZATION MULTIPLIER (DIMENSIONLESS)

NBADT : NORTH BANK AVERAGE DAILY TRAFFIC (TRIPS/DAY)
 NBBR : NORTH BANK BIRTH RATE (PEOPLE/YEAR)
 NBBRN : NORTH BANK BIRTH RATE NORMAL (FRACTION)
 NBBS : NORTH BANK BUSINESS STRUCTURES (BUSINESS)
 NBBSC : NORTH BANK BUSINESS STRUCTURES CONSTRUCTION (BUSINESS/YEAR)
 NBBSCN : NORTH BANK BUSINESS STRUCTURES CONSTRUCTION NORMAL
 NBBSD : NORTH BANK BUSINESSSTRUCUTURES DETERIORATION(BUSINESS/YEAR)
 NBBSDN : NORTH BANK BUSINESS STRUCTURES DETERIORATION NORMAL
 (FRACTION)

NBCLA : NORTH BANK CIVIC LAND AREA (ACRES)
 NBCLAM : NORTH BANK CIVIC LAND AVAILABILITY MULTIPLIER

NBCLAN : NORTH BANK CIVIC LAND AREA NORMAL (ACRES)
 NBCLO : NORTH BANK CIVIC LAND FRACTION OCCUPIED (FRACTION)
 NBDR : NORTH BANK DEATH RATE (PEOPLE/YEAR)
 NBDRN : NORTH BANK DEATH RATE NORMAL (FRACTION)
 NBEET : NORTH BANK EXTERNAL EXTERNAL TRIPS (TRIPS/DAY)
 NBEETG : NORTH BANK EXTERNAL EXTERNAL TRIP GROWTH (TRIPS/DAY)
 NBEETGN : NORTH BANK EXTERNAL EXTERNAL TRIP GROWTH NORMAL (FRACTION)
 NBH : NORTH BANK HOUSES (HOUSES)
 NBHC : NORTH BANK HOUSING CONSTRUCTION (HOUSES/YEAR)
 NBHCN : NORTH BANK HOUSING CONSTRUCTION NORMAL (FRACTION)
 NBHDR : NORTH BANK HOUSING DETERIORATION RATE (HOUSES/YEAR)
 NBHDRN : NORTH BANK HOUSING DETERIORATION RATE NORMAL (FRACTION)
 NBI : NORTH BANK IMMIGRATION (PEOPLE/YEAR)
 NBIENWT : NORTH BANK INTERNAL EXTERNAL NOW WORK TRIPS (TRIPS/DAY)
 NBIET : NORTH BANK INTERNAL EXTERNAL TRAFFIC (TRIPS/DAY)
 NBIEWT : NORTH BANK INTERNAL EXTERNAL WORK TRIPS (TRIPS/DAY)
 NBJ : NORTH BANK JOBS (JOBS)
 NBLA : NORTH BANK LAND AREA (ACRES)
 NBLAM : NORTH BANK LAND AVAILABILITY MULTIPLIER (DIMENSIONLESS)
 NBLF : NORTH BANK LAND AREA (ACRES)
 NBLFO : NORTH BANK LAND FRACTION OCCUPIED (FRACTION)
 NBPHF : NORTH BANK PEAK HOUR FLOWS (PASSENGER CAR UNITS/HOUR)
 NBPOP : NORTH BANK POPULATION (PEOPLE)
 NBSGLG : NORTH BANK SUGAR LAND GROWTH (ACRES/YEAR)
 NBSL : NORTH BANK SUGAR LAND (ACRES)
 NBSLC : NORTH BANK SUGAR LAND CONVERSION (ACRES/YEAR)
 NBSLCN : NORTH BANK SUGAR LAND CONVERSION NORMAL (FRACTION)
 NBSLGN : NORTH BANK SUGAR LAND GROWTH NORMAL (INDUSTRIES)
 NBSMI : NORTH BANK SUGAR MANUFACTURING INDUSTRY (INDUSTRIES)
 NBSMIG : NORTH BANK SUGAR MANUFACTURING INDUSTRY GROWTH
 NBSMIGN : NORTH BANK SUGAR MANUFACTURING INDUSTRY GROWTH NORMAL
 NBSS : NORTH BANK SERVICE STRUCTURES (SERVICE STRUCTURES)
 NBSSC : NORTH BANK SERVICE STRUCTURES CONSTRUCTION (STRUCTURES/YEAR)
 NBSSCN : NORTH BANK SERVICE STRUCTURE CONSTRUCTION NORMAL (FRACTION)
 NBSSD : NORTH BANK SERVICE STRUCTURES DETERIORATION RATE (STRUCTURES)
 NBSSDN : NORTH BANK SERVICE STRUCTURES DETERIORATION NORMAL
 NBTRT : NORTH BANK TRUCK TRIPS (TRIPS/DAY)
 NBTRTG : NORTH BANK TRUCK TRIP GROWTH (TRIPS /DAY)
 NBTRTGN : NORTH BANK TRUCK TRIP GROWTH NORMAL (FRACTION)
 NBUR : NORTH BANK UNEMPLOYMENT RATE (PERCENT)
 NBMLA : NORTH BANK MANUFACTURE LAND AVAILABLE (FEET)
 NBMLAM : NORTH BANK MANUFACTURE LAND AVAILABILITY MULTIPLIER
 NBMLFO : NORTH BANK MANUFACTURE LAND FRACTION OCCUPIED (FRACTION)
 NBMS : NORTH BANK MANUFACTURE STRUCTURES (MANUFACTURES)
 NBMSC : NORTH BANK MANUFACTURE STRUCTURES CONSTRUCTION
 (MANUFACTURES /YEAR)
 NBMSCN : NORTH BANK MANUFACTURE STRUCTURES CONSTRUCTION NORMAL
 (FRACTION)
 NBMSD : NORTH BANK MANUFACTURE STRUCTURES DETERIORATION
 (MANUFACTURE/YEAR)
 NBMSDN : NORTH BANK MANUFACTURE STRUCTURES DETERIORATION NORMAL
 (FRACTION)
 NF : NEW FARMERS (FARMERS)
 NLDA : NORMAL LABOR COST PER ACRE (\$/ACRE)
 NMICA : NORMAL MECHANICAL INPUT COST (\$/ACRE)
 NPH : NUMBER OF PERSONS PER HOUSE (PEOPLE/HOUSE)
 NRCA : NORMAL LAND RENTAL COST (\$/ACRE)
 NUR : NATIONAL UNEMPLOYMENT RATE (PERCENT)

OFLC : OFFLOADING COST PER TON (\$/TON)
 OFLT : OFFLOADING TIME (DAYS)
 ONLC : ONLOADING COST PER TON (\$/TON)
 ONLT : ONLOADING TIME (DAYS)

PA : PERCENT BY AUTO (FRACTION)
 PB : PERCENTAGE BY BUS (FRACTION)
 PFRM : PROFIT FROM RICE FARMING MULTIPLIER (DIMENSIONLESS)
 PH : PERSON PER HOUSE (PEOPLE/HOUSE)
 PHP : PEAK HARVEST PERIOD (DAYS)
 PLPT : PAYLOAD PER TRUCK (TONS/ TRUCK)
 PLPV : PAY LOAD PER VESSEL (TONS/VESSEL)
 PPA : PROFIT PER ACRE (\$/ACRE)
 PPH : PERCENT PER PEAD HOUR (FRACTION)

QDCT : QUEUE DELAY COST PER TON (\$/TON)
 QDM : QUEUE DELAY MULTIPLIER (DIMENSIONLESS)
 QDMT : QUEUE DELAY MULTIPLIER GRAPH FUNCTION
 QDPV : QUEUE DELAY VESSELS MULTIPLIER (DIMENSIONLESS)
 QTR : QUANTITY TO BE TRANSPORTED BY RAIL (TONS/CROP)

RAMLD : ROAD ACCESSIBILITY MULTIPLIER (DIMENSIONLESS)
 RBR : RURAL BIRTH RATE (PEOPLE/YEAR)
 RBRN : RURAL BIRTH RATE NORMAL (FRACTION)
 RCB : ROAD CONSTRUCTION BUDGET (\$)
 RCE : ROAD CONSTRUCTION EXPENSES(\$)
 RCPC : RICE CONSUMPTION PER CAPITA (TONS/PERSON)
 RCR : ROAD CONSTRUCTION RATE (MILES /YEAR)
 RCT : ROAD CONSTRUCTION TIME (YEAR)
 RDFLO : ROAD LAND FRACTION OCCUPIED (FRACTION)
 RDLA : ROAD LAND AVAILABLE (ACRES)
 RDR : RURAL DEATH RATE (PEOPLE/YEAR)
 RDRN : RURAL DEATH RATE NORMAL (FRACTION)
 PER : ROAD EXPENSES (\$)
 RF : RURAL FUND (\$)
 RFAT : REGIONAL FRACTION OF AGRICULTURAL TECHNICIANS(FRACTION)
 RFD : RICE FOR DISTRIBUTION (TONS)
 RFMR : RICE FARMERS (FARMERS)
 RFN : ROAD FUND NORMAL (\$)
 RFR : ROAD FUNDING RATE (\$/YEAR)
 RFRN : ROAD FUNDING RATE NORMAL (FRACTIONA)
 RH : RURAL HOUSES (HOUSES)
 RHC : RURAL HOUSING CONSTRUCTION(HOUSES/YEAR)
 RHCM : RURAL HOUSING CONSTRUCTION MULTIPLIER (DIMENSIONLESS)
 RHCN : RURAL HOUSING CONSTRUCTION NORMAL (FRACTION)
 RHD : RURAL HOUSES DETERIORATION (HOUSES/YEAR)
 RHDN : RURAL HOUSES DETTERIORATION NORMAL (FRACTION)
 RHHR : RURAL HOUSEHOLDS TO HOUSES RATIO (FRACTION)
 RL : RICE LAND (ACRES)
 RLA : RURAL LAND AREA (ACRES)
 RLCM : RICE LAND CONVERSION MULTIPLIER (DIMENSIONLESS)
 RLCR : RICE LAND CONVERSION RATE (ACRES/YEAR)
 RLCRN : RICE LAND CONVERSION RATE NORMAL (FRACTION)
 RLDM : RICE LAND DEVELOPMENT MULTIPLIER (DIMENSIONLESS)
 RLDR : RICE LAND DEVELOPMENT RATE (ACRES/YEAR)
 RLF : RURAL LABOR FORCE (PEOPLE)
 RLFO : RURAL LAND FRACTION OCCUPIED (FRACTION)
 RLHR : RICE TO HARVESTER RATIO (FRACTION)
 RLHRM : RICE TO HARVESTER MULTIPLIER (DIMENSIONLESS)

RLI	: LIMIT OF IRRIGATION AREA (ACRES)
RLTWR	: RICE LAND TO WATER RATIO (FRACTION)
RM	: RURAL MIGRATION (PEOPLE/YEAR)
RMB	: ROAD MAINTENANCE BUDGET (\$)
RME	: ROAD MAINTENANCE EXPENSES (\$)
RMM	: ROAD MAINTENANCE MULTIPLIER (DIMENSIONLESS)
RP	: RURAL POPULATION (PEOPLE)
RPPF	: RURAL POPULATION PARTICIPATION FRACTION (FRACTION)
RRDR	: ROAD DETERIORATION RATE (MILES/YEAR)
RRLAM	: ROAD LAND AVAILABILITY MULTIPLIER (DIMENSIONLESS)
RROAD	: RURAL ROAD (MILES)
RTC	: ROAD TRANSPORT CAPACITY (TONS/CROP)
RTCPR	: RAIL TRANSPORT CAPACITY PER ROUTE (TONS/CROP)
RTCT	: RAIL TRANSPORT COST PER TON (\$/TON)
RTMC	: ROAD TRANSPORT MODE COST (\$/TON)
RTMCN	: ROAD TRANSPORT MODE COST NORMAL (\$/TON)
RTR	: RAIL TRANSPORT RATE (TON/ACRE)
RTRCR	: ROAD TO RAIL TRANSPORT COSTS RATIO MULTIPLIER
RUR	: RURAL UNEMPLOYMENT RATE (PERCENT)
RURM	: RURAL UNEMPLOYMENT MULTIPLIER GRAPH FUNCTION
SPADT	: SOUTH PA-CHANG AVERAGE DAILY TRAFFIC (TRIPS/DAY)
SPBR	: SOUTH PA-CHANG BIRTH RATE (PEOPLE/YEAR)
SPBRN	: SOUTH PA-CHANG BIRTH RATE NORMAL (FRACTION)
SPBS	: SOUTH PA-CHANG BUSINESS STRUCTURES (BUSINESS STRUCTURES)
SPBSC	: SOUTH PA-CHANG BUSINESS STRUCTURES CONSTRUCTION
SPBSCN	: SOUTH PA-CHANG BUSINESS STRUCTURES CONSTRUCTION NORMAL (FRACTION)
SPBSD	: SOUTH PA-CHANG BUSINESS STRUCTURES DETERIORATION
SPBSDN	: SOUTH PA-CHANG BUSINESS STRUCTURES DETERIORATION NORMAL
SPCLA	: SOUTH PA-CHANG CIVIC LAND AREA (ACRES)
SPCLA	: SOUTH PA-CHANG CIVIC LAND AREA (ACRES)
SPCLAM	: SOUTH PA-CHANG CIVIC LAND AVAILABILITY MULTIPLIER
SPCLAN	: SOUTH PA-CHANG CIVIC LAND AREA NORMAL (ACRES)
SPCLFO	: SOUTH PA-CHANG CIVIC LAND FRACTION OCCUPIED (FRACTION)
SPCLO	: SOUTH PA-CHANG CIVIC LAND FRACTION OCCUPIED (FRACTION)
SPDR	: SOUTH PA-CHANG DEATH RATE (PEOPLE/YEAR)
SPDRN	: SOUTH PA-CHANG DEATH RATE NORMAL (FRACTION)
SPEET	: SOUTH PA-CHANG EXTERNAL EXTERNAL TRIPS (TRIPS/DAY)
SPEETG	: SOUTH PA-CHANG EXTERNAL EXTERNAL TRIPS GROWTH (TRIPS/ DAY)
SPEETGN	: SOUTH PA-CHANG EXTERNAL EXTERNAL TRIPS GROWTH NORMAL
SPEIT	: SOUTH PA-CHANG EXTERNAL INTERNAL TRIPS (TRIPS/DAY)
SPEITG	: SOUTH PA-CHANG EXTERNAL INTERNAL TRIPS (TRIPS/DAY)
SPEITGN	: SOUTH PA-CHANG EXTERNAL INTERNAL TRIPS GROWTH NORMAL
SPH	: SOUTH PA-CHANG HOUSES (HOUSES)
SPHC	: SOUTH PA-CHANG HOUSING CONSTRUCTION (HOUSES/YEAR)
SPHCN	: SOUTH PA-CHANG HOUSING CONSTRUCTION NORMAL (FRACTION)
SPHDR	: SOUTH PA-CHANG HOUSING DETERIORATION (HOUSES/YEAR)
SPHDRN	: SOUTH PA-CHANG HOUSING DETERIORATION NORMAL (FRACTION)
SPI	: SOUTH PA-CHANG IMMIGRATION (PEOPLE/YEAR)
SPIENWT	: SOUTH PA-CHANG INTERNAL EXTERNAL NON WORK TRIPS (TRIPS/DAY)
SPIET	: SOUTH PA-CHANG INTERNAL EXTERNAL TRAFFIC (TRIPS/DAY)
SPIEWT	: SOUTH PA-CHANG INTERNAL EXTERNAL WORK TRIPS (TRIPS/DAY)
SPJ	: SOUTH PA-CHANG JOBS (JOBS)
SPLAM	: SOUTH PA-CHANG LAND AVAILABILITY MULTIPLIER (DIMENSIONLESS)
SPLF	: SOUTH PA-CHANG LABOR FORCE (PEOPLE)
SPMS	: SOUTH PA-CHANG MANUFACTURING STRUCTURES (SERVICE STRUCTURES)
SPMSC	: SOUTH PA-CHANG MANUFACTURING CONSTRUCTION (STRUCTURES/YEAR)

SPMSCN : SOUTH PA-CHANG MANUFACTURING CONSTRUCTION NORMAL
 SPMSD : SOUTH PA-CHANG MANUFACTURING DETERIORATION
 SPMSDN : SOUTH PA-CHANG MANUFACTURING DETERIORATION NORMAL
 SPOCL : SOUTH PA-CHANG OTHER CROP LADN (ACRES)
 SPOCLG : SOUTH PA-CHANG OTHER CROP LADN GROWTH (ACRES/YEAR)
 SPOCLGN : SOUTH PA-CHANG OTHER CROP LAND GROWTH NORMAL (FRACTION)
 SPPHF : SOUTH PA-CHANG PEAK HOUR FLOW (TRIPS/HOUR)
 SPT : SELLING PRICE OF UNMILLED RICE PER TON (\$/TON)
 SPSL : SOUTH PA-CHANG SUGAR LAND (ACRES)
 SPSLC : SOUTH PA-CHANG SUGAR LAND CONVERSION (ACRES/YEAR)
 SPSLCN : SOUTH PA-CHANG SUGAR LAND CONVERSION NORMAL (FRACTION)
 SPSLG : SOUTH PA-CHANG SUGAR LAND GROWTH (ACRES/YEAR)
 SPSLGN : SOUTH PA-CHANG SUGAR LAND GROWTH NORMAL (FRACTION)
 SPSMI : SOUTH PA-CHANG SUGAR MANUFACTURING INDUSTRY (INDUSTRIES)
 SPSMIG : SOUTH PA-CHANG SUGAR MANUFACTURING INDUSTRY GROWTH
 SPSMIGN : SOUTH PA-CHANG SUGAR MANUFACTURING INDUSTRY GROWTH NORMAL
 SPSS : SOUTH PA-CHANG SERVICE STRUCTURES (SERVICE STRUCTURES)
 SPSSC : SOUTH PA-CHANG SERVICE STRUCTURES CONSTRUCTION
 (STRUCTURES/YEAR)
 SPSSCN : SOUTH PA-CHANG SERVICE STRUCTURES CONSTRUCTION NORMAL
 SPSSD : SOUTH PA-CHANG SERVICE STRUCTURES DETERIORATION
 SPSSDN : SOUTH PA-CHANG SERVICE STRUCTURES DETERIORATION NORMAL
 SPTRT : SOUTH PA-CHANG TRUCK TRIPS (TRIPS/DAY)
 SPTRTG : SOUTH PA-CHANG TRUCK TRIPS GROWTH (TRIPS/DAY)
 SPTRTGN : SOUTH PA-CHANG TRUCK TRIPS GROWTH NORMAL (FRACTION)
 SPUR : SOUTH PA-CHANG UNEMPLOYMENT RATE (PERCENT)

TDN : TRUCK DEPRECIATION NORMAL (FRACTION)
 TDR : TRUCK DEPRECIATION RATE (TRUCKS/YEAR)
 TDRM : TRUCK DEPRECIATION RATE MULTIPLIER (DIMENSIONLESS)
 TE : TRUCK EQUIVALENT (PASSENGER CAR UNITS/TRUCK)
 TPJ : TRIPS PER JOB (DAILY TRIPS/JOB)
 TPP : TRIPS PER POPULATION (DAILY TRIPS/PERSON)
 TPR : TRUCK PURCHASE RATE (TRUCK/YEAR)
 TPV : TRIPS PER VESSEL (TRIPS/VESSEL/CROP)
 TR : TRACTORS
 TRDR : TRACTOR DEPRECIATION RATE (TRACTORS/YEAR)
 TRDRN : TRACTOR DEPRECIATION RATE NORMAL (FRACTION)
 TRPR : TRACTOR PURCHASE RATE (TRACTORS/YEAR)
 TRT : TECHNICIAN TRAINING TIME (YEAR)
 TRUCK : TRUCKS
 TT : TRUCK TRIPS (TRIPS/CROP)
 TTC : TRAVEL TIME COST PER TON (\$/TON)
 TTM : TRUCK TRAFFIC MULTIPLIER (DIMENSIONLESS)
 TIPD : TRUCK TRIPS PER DAY (TRIPS/DAY)

UFCHJ : UNFILLED CHANG-HWA CITY JOBS (JOBS)
 UH : URBAN HOUSES (HOUSES)
 UHRH : URBAN HOUSEHOLDS TO HOUSES RATIO (FRACTION)
 UI : URBAN INMIGRATION (PEOPLE/YEAR)
 UIM : URBAN INMIGRATION MULTIPLIER (DIMENSIONLESS)
 UIN : URBAN INMIGRATION NORMAL (FRACTION)
 UJ : URBAN JOBS (JOBS)
 ULF : URBAN LABOR FORCE (PEOPLE)
 ULFAM : URBAN LABOR FORCE AVAILABILITY (DIMENSIONLESS)
 ULFTJR : URBAN LABOR FORCE TO JOBS RATIO (FRACTION)
 UMRL : UNMILLED RICE LOSS (TONS/CROP)
 UMRPR : UNMILLED RICE PRODUCTION RATE (TONS/CROP)
 UMRTR : UNMILLED RICE TRANSPORT RATE (TONS/CROP)

UPOP : URBAN POPULATION (PEOPLE)
 UUR : URBAN UNEMPLOYMENT RATE (PERCENT)

 VCPD : VESSEL COST PER DAY (\$/DAY)
 VDSER : VESSEL DETERIORATION RATE (VESSELS/YEAR)
 VDESRN : VESSEL DETERIORATION RATE NORMAL (FRACTION)
 VIS : VESSELS
 VPR : VESSEL PURCHASE RATE (VESSELS/YEAR)

 WCADT : WEST COAST AVERAGE DAILY TRAFFIC (TRIPS/DAY)
 WCBR : WEST COAST BIRTH RATE (PEOPLE/YEAR)
 WCBRN : WEST COAST BIRTH RATE NORMAL (FRACTION)
 WCBS : WEST COAST BUSINESS STRUCTURES (BUSINESS STRUCTURES)
 WCBCS : WEST COAST BUSINESS STRUCTURES CONSTRUCTION
 WCBCSN : WEST COAST BUSINESS STRUCTURES CONSTRUCTION NORMAL (FRACTION)
 WCBSD : WEST COAST BUSINESS STRUCTURES DETERIORATION
 WCBSDN : WEST COAST BUSINESS STRUCTURES DETERIORATION NORMAL
 WCCLA : WEST COAST CIVIC LAND AREA (ACRES)
 WCCLA : WEST COAST CIVIC LAND AREA (ACRES)
 WCCLAM : WEST COAST CIVIC LAND AVAILABILITY MULTIPLIER
 WCCLAN : WEST COAST CIVIC LAND AREA NORMAL (ACRES)
 WCCLFO : WEST COAST CIVIC LAND FRACTION OCCUPIED (FRACTION)
 WCCLO : WEST COAST CIVIC LAND FRACTION OCCUPIED (FRACTION)
 WCDR : WEST COAST DEATH RATE (PEOPLE/YEAR)
 WCDRN : WEST COAST DEATH RATE NORMAL (FRACTION)
 WCEET : WEST COAST EXTERNAL EXTERNAL TRIPS (TRIPS/DAY)
 WCEETG : WEST COAST EXTERNAL EXTERNAL TRIPS GROWTH (TRIPS/DAY)
 WCEETGN : WEST COAST EXTERNAL EXTERNAL TRIPS GROWTH NORMAL
 WCEIT : WEST COAST EXTERNAL INTERNAL TRIPS (TRIPS/DAY)
 WCEITG : WEST COAST EXTERNAL INTERNAL TRIPS (TRIPS/DAY)
 WCEITGN : WEST COAST EXTERNAL INTERNAL TRIPS GROWTH NORMAL
 WCH : WEST COAST HOUSES (HOUSES)
 WCHC : WEST COAST HOUSING CONSTRUCTION (HOUSES/YEAR)
 WCHCN : WEST COAST HOUSING CONSTRUCTION NORMAL (FRACTION)
 WCHDR : WEST COAST HOUSING DETERIORATION (HOUSES/YEAR)
 WCHDRN : WEST COAST HOUSING DETERIORATION NORMAL (FRACTION)
 WCI : WEST COAST IMMIGRATION (PEOPLE/YEAR)
 WCINWT : WEST COAST INTERNAL EXTERNAL NON WORK TRIPS (TRIPS/DAY)
 WCJET : WEST COAST INTERNAL EXTERNAL TRAFFIC (TRIPS/DAY)
 WCJETW : WEST COAST INTERNAL EXTERNAL WORK TRIPS (TRIPS/DAY)
 WCJ : WEST COAST JOBS (JOBS)
 WCLAM : WEST COAST LAND AVAILABILITY MULTIPLIER (DIMENSIONLESS)
 WCLF : WEST COAST LABOR FORCE (PEOPLE)
 WCOCL : WEST COAST OTHER CROP LAND (ACRES)
 WCOCLG : WEST COAST OTHER CROP LAND GROWTH (ACRES/YEAR)
 WCOCLGN : WEST COAST OTHER CROP LAND GROWTH NORMAL (FRACTION)
 WCPHF : WEST COAST PEAK HOUR FLOW (TRIPS/HOUR)
 WCSL : WEST COAST SUGAR LAND (ACRES)
 WCSLC : WEST COAST SUGAR LAND CONVERSION (ACRES/YEAR)
 WCSLCN : WEST COAST SUGAR LAND CONVERSION NORMAL (FRACTION)
 WCSLG : WEST COAST SUGAR LAND GROWTH (ACRES/YEAR)
 WCSLGN : WEST COAST SUGAR LAND GROWTH NORMAL (FRACTION)
 WCSMI : WEST COAST SUGAR MANUFACTURING INDUSTRY (INDUSTRIES)
 WCSMIG : WEST COAST SUGAR MANUFACTURING INDUSTRY GROWTH
 WCSMIGN : WEST COAST SUGAR MANUFACTURING INDUSTRY GROWTH NORMAL
 WCSS : WEST COAST SERVICE STRUCTURES (SERVICE STRUCTURES)
 WCSSC : WEST COAST SERVICE STRUCTURES CONSTRUCTION (STRUCTURES/YEAR)
 WCSSCN : WEST COAST SERVICE STRUCTURES CONSTRUCTION NORMAL
 WCSSD : WEST COAST SERVICE STRUCTURES DETERIORATION

WCSSDN : WEST COAST SERVICE STRUCTURES DETTERIORATION NORMAL
WCTRT : WEST COAST TRUCK TRIPS (TRIPS/DAY)
WCTRTG : WEST COAST TRUCK TRIPS GROWTH (TRIPS/DAY)
WCTRTGN : WEST COAST TRUCK TRIPS GROWTH NORMAL (FRACTION)
WCUR : WEST COAST UNEMPLOYEMNT RATE (PERCENT)
WPRA : WATER REQUIREMENT PER ACRE (ACRE-FEET/ ACRE)

YPA : YIELD PER ACRE (TONS/ACRE)
YPAN : YIELD PER ACRE NORMAL (TONS/ACRE)