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**THE DEVELOPMENT OF A SYSTEM DYNAMICS SIMULATION MODEL OF
NATIONAL PARK REGIONS FOR EDUCATIONAL USE**

By

Kuan-Chou Chen

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
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Department of Park, Recreation and Tourism Resources

1995

ABSTRACT

THE DEVELOPMENT OF A SYSTEM DYNAMICS SIMULATION MODEL OF NATIONAL PARK REGIONS FOR EDUCATIONAL USE

By

Kuan-Chou Chen

Problems related to National Parks regional planning and economic development that must be addressed by educators today have become increasingly complex, ambiguous, and interrelated. Traditional classroom teaching styles, including lecture and discussion which are passive and often neglect real world issues, have proven inadequate to address the growing complexity of National Park regional systems, particularly with regard to regional economic development concerns. Learning is most effective as part of an interactive, discovery-oriented process, and, in order to more effectively understand complex real world systems, teaching styles that encourage hands-on, experiential learning should be used.

The System Dynamics modeling approach described and employed in this dissertation effectively demonstrates how System Dynamics can be used to construct a model of complex systems as a pedagogical tool to understand National Park planning, economic development processes and dynamic system behavior.

The interrelationship of seven primary sectors that are at the foundation of National Parks regional development are modeled in this research: population, capital allocation, industry, social overhead, environment, economics, and tourism and recreation.

Particular emphasis is directed at enhancing understanding of environmental impact and economic development which are of growing concern in both park system planning and the education of future park managers.

Two System Dynamics methods, Qualitative System Dynamics and Quantitative System Dynamics are used in model development. The resulting model facilitates understanding of how the processes and other elements of systems interact to create system behavior. The model also establishes a set of National Parks regional system variables that can be manipulated by students and teachers through an interactive gaming simulation interface to experiment with different variables and outcomes.

The interactive experiential teaching and learning tool developed and described in this study can be used effectively by educators and students in the learning process. A gaming simulation application, teaching procedures, and a simulation case study are developed and explained to demonstrate ways in which the interactive gaming simulation application can be used effectively by instructors and students in the classroom. In addition, academic programs and curricular plans that utilize the interactive simulation model are discussed to assist educators in developing related courses and integrating these tools and information into existing courses and curricula.

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During the past four years, I have worked in three programs at Michigan State University simultaneously (Park, Recreation & Tourism, Economics, and Resource Economics). Without the encouragement, assistance, and support from my family, friends, committee members, and fellow students the work I have completed would not have been possible.

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And, of course, words cannot express my appreciation and gratitude for the love, sacrifice, support, and encouragement so generously given by my wife, Keh-Wen, and my lovely daughter, Emily.

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CHAPTER I

INTRODUCTION

The Problem

National Park regions contain a number of natural resources such as beautiful scenery, diverse wildlife, and vegetation most of which provide great opportunities for recreation and create substantial economic impacts on local communities. Also, due to the rural nature of many regions which contain National Parks, the economies of these regions tend to rely heavily on one or a few major industries and thus lack the economic diversity of metropolitan areas. In these areas, tourism and recreation generally play a large role in local economies. In other words, the National Park systems of such regions are tightly interrelated with their socio-economic systems. Indeed, National Park systems will usually affect the way in which related socio-economic systems grow and change. And changes in socio-economic systems will in turn call forth changes in National Park systems. This interrelationship is fundamental to the view of National Park system analysis taken in this dissertation.

How can (should) a National Park region gain or use comparative advantage to obtain economic revitalization and/or use natural resources, while also maintaining the environmental integrity of the related land resources and preserving the park's unique character? The answer to this question surely must incorporate information about the local

economy and its regional setting. In any such answer, economic development and protection of the natural environment should be mutually supportive goals. On the other hand, economic development increases the complexity of not only the interrelationships with other regional subsystems but the interdependencies between its subsystems.

In most classroom settings, instructors typically use a combination of lecture and discussion to teach natural resources based regional economic development topics. While both the lecture and discussion formats are useful to explain complex subsystems, they often can fall short of realizing their potential. Lectures can easily become one-way avenues for communication. Students can rapidly lose sight of the big picture, as they furiously strive to take notes on the specific information elements being presented. Many instructors lack the knowledge and experience to facilitate truly effective classroom discussion, and as a result, classroom discussion can also easily lose its focus. A handful of students can gain dominance over the discussion, causing it to drift into narrow tangential areas while the remainder of the students lose interest in the material being discussed and its broader implications. Educators must accept and respond to the need for effective analytical frameworks that help students understand key concepts within the context of real world problems and concerns (Meyers, 1986). In the past ten years, it appears that the use of “hands-on experimentation” in the social sciences, natural resources and humanities, has improved the discipline and rigor of the thinking processes of students in these disciplines. Research during this time suggests that teaching styles that encourage and utilize hands-on

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experimentation are more effective than lecture or discussion style in these disciplines (Richmond, 1985; Youtz, 1984; Perry, 1981; Morecraft, 1982). Educational tools such as the System Dynamics model developed as part of this study offer a practical, real-world framework for students that encourages critical exploration and effective classroom discussion.

Instructors of natural resource management classes must understand the regional economy, the implications of alternative economic policies, and answer questions raised by students. In addition to compiling and analyzing basic facts, they must develop effective learning/teaching models and strategies. To effectively address these broad issues, there is an acute need to develop a theoretical analysis framework, a set of tools that can open new avenues for focused communication. Similarly, a sound and practical holistic model for the simultaneous analyses of National Park regional development options with emphasis on economic development issues is necessary to engage students in active learning experiences.

The Meaning of National Park Regional Development and Planning

In essence “development” means “resource development” achieved through a production process which increases the utility of resources. Manufacturing (the conversion of raw materials to final goods) is an obvious example of production; but so are transportation (the conveyance of materials from one place to another), inventory or storage (the retention of materials from one time to another), and construction (the

combination of materials into building components and systems). Thus, value added to the resource may be accomplished through the creation of form utility (manufacturing and construction), space utility (transportation), or time utility (inventory or storage).

National Park regional development, then, is a process by which the natural endowments of a region are captured by one or all of the following: appropriate management, skill, technology, and socio-cultural appreciation. The end uses generally include such things as household consumption, public service, capital accumulation, conservation and preservation, tourism and recreation, education, and self-satisfaction.

It is clear that development is an evolutionary process. The phenomenon of development always exists in any human related system, such as a nation, a region, or a city. The point is not to identify the importance of development, but to determine how development can be matched to goals.

Planning is recognized as a complex and many-sided phenomenon. It is, or at least should be, an organized, intelligent attempt to select the best available alternatives to achieve specific goals. The goals may range from putting men into outer space to the management of an enterprise, a city, or a whole country. Planning can be temporary, as in planning in times of emergencies such as war or national disaster, or it can be permanent and long term, as in national planning for economic development.

Regional planning seeks to bring the physical environment in which men live under the controlling influence of the public interest. In other words, the purpose of

regional planning has usually been interpreted as achieving economic progress through physical resource development. Both regional development and regional planning imply the effort to search for the optimum utilization of the natural endowments of a region to attain economic and social progress. Planning for development is pervasive--- it is a most urgent task facing the countries of the world.

Role of Economics in Regional Development

The economic system can be divided into two broad categories, macroeconomics and microeconomics. Macroeconomics in general considers the broad reach of economic theory as developed at a regional, national or international scale. Components of this economic system category are represented by an aggregation of the actions of a multitude of individual elements such as firms, persons or groups. The observation period used to gather information is, in comparison to most other systems, quite long, varying from one quarter year to an entire year. In microeconomics, the economic system of concern is much smaller in scale than are macroeconomic systems and might represent a particular firm to a producer-distributor-consumer sector in a given geographical region. The focus of economics in regional development has been on big economic issues in terms of what can happen to the economy and why. Each of these issues involves the overall economic performance of the region, rather than that of particular individual sectors or economic units. For instance, do regional residents find it easy or difficult to find jobs? How much total income is the region producing, and how rapid is income growing year after year?

By applying macroeconomics theory to regional economic development, it is easier to see more detailed characteristics of that region. For example, it might be found that tourism and recreation is the most important sector stimulating economic development in a particular National Park region.

Economic development is a process whereby an economy's real income increases over a long period of time. And, if the rate of development is greater than the rate of population growth, the per capita real income will increase (Meier & Baldwin, 1957). "Process" implies the operation of certain forces; these forces operate over a long period and embody changes in certain variables. Details of the process vary over differing space and time conditions, but there are some common features. The general result of the process is growth in an economy's product---in itself a particular long-run change.

Regional economic development in the sense in which it has been described above, necessarily involves certain fundamental changes in the structure of the economy. These changes occur both on the demand and supply side. These changes include: (1) the discovery of additional resources, (2) capital accumulation, (3) population growth, (4) introduction of new and better techniques of production, (5) improvement in skills, and (6) other institutional and organizational modifications (Meier & Baldwin, 1957; Fernando & Kambli, 1971; Donaldson, 1984).

The Gaming-simulation Model as an Educational Tool

Gaming and simulation are experimental activities that have gained acceptance in classrooms at all levels of education and training and in a variety of subject areas (Gredler, 1992). In practice, a “game” refers to a teaching exercise in which interaction among learners is an important component. More specifically, a “game” usually means an exercise, defined by a set of rules, which can be played by two or more participants. The rules define how the game is supposed to be played and how it is ended.

The term simulation is used to describe a variety of attempts to represent “real world” activities in such a way that “players” may manipulate selected variables and experiment with their interrelationships. A simulation may focus on only a few components of a system or process, or it may entail a complex set of variables. Some simulations are physical representations of systems as illustrated by flight trainers and architectural models. Simulations of management processes and transportation systems are usually represented mathematically and generally embedded in computer programs. Land use simulations often rely upon graphic representations. The simulation in this research is implemented in a computer graphic-based system and is designed in gaming style.

Objectives of this Study

The purpose of this study is to design a theoretical and applicable model using the System Dynamics approach that can be used in natural resources management training and instruction. This model can assist natural resources administrators, economists, planners and classroom instructors in organizing the regional economic development elements in National Park regions. The educational uses of the generic model, rather than focusing on presentation of facts, focuses on building skill in the use of facts. The specific objectives are as follows:

1. To provide sufficient tools and guides to permit the widespread use of the System Dynamics simulation model for educational uses in National Park regional planning. These tools and knowledge can be used for simulation experimentation and as the basis for comprehensive System Dynamics modeling and regional planning courses.
2. To apply a suitable methodology for establishing an integrated model to organize expert knowledge and theory into a meaningful scheme for educational purposes, and to serve as a development planning laboratory to perform policy formulation and testing by evaluating performance and behavior of significant variables.
3. To construct a dynamic, graph-based operational computer model that can simulate the process of National Park regional planning and development. In the process of gaming simulation, this model will demonstrate for students the impact of recreation

and tourism and population and natural resources issues on the regional planning and development process.

Potential Uses of the Study

The development of a National Park regional simulation model based on the domain of economic development would provide a means to:

1. Identify elements in National Park regions that may be controlled to improve economic development.
2. Identify and structure National Park system planning rules that determine the inferential processes of economic development.
3. Model how changes in economic development policy may change the responsibilities of both providers and consumers of tourism and recreation.

Organization of the Study

This dissertation consists of five chapters. In Chapter I, the problem, the relevant terminology, and the objectives and potential uses of the study are presented.

In Chapter II, a description of the system model and its components is provided without extensive use of mathematics. This chapter also serves to discuss the modeling approach employed in this research. Approaches to system modeling are briefly reviewed. The reasons why System Dynamics simulation was selected for use in this study are presented. Reviews of related applications of System Dynamics in economic

development are presented to increase the understanding and familiarity with the methodology used.

In Chapter III, the concept of System Dynamics is presented in conjunction with Qualitative System Dynamics of causal feedback loops used to describe the basic structure underlying the development process. The overall Quantitative System Dynamics of the regional model, upon which the dynamic behavior of regional economic development is based, is introduced. Finally, connections between verbal descriptions of the behavior of some of the key variables to the System Dynamics equations is given.

In Chapter IV, a basic simulation run of the National Park regional model is presented. The development of the region is represented by some of the most significant variables. The consequences and implication of these outputs are discussed. The application of gaming simulation, teaching procedures, and a simulation case study are explained and developed to demonstrate ways in which the interactive gaming simulation application can be used effectively by instructors and students in the classroom. In addition, academic programs and curricular plans that utilize the interactive simulation model are discussed to assist educators in developing related courses and integrating these tools and information into existing courses and curricula.

The last chapter, Chapter V, functions as a recapitulation of preceding chapters. It also reports this author's perceptions of the overall usefulness and success of this research effort. Finally, the limitations of this study and recommendations are made for

improvements and additions that should increase the utility of this and similar models that may be developed in the future.

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CHAPTER II

GENERAL DESCRIPTION OF THE SYSTEM MODEL

Introduction

In this chapter, the National Park regional model will be described in general terms. This chapter begins with a discussion of the general focus of the model. The processes that have been modeled and the variables used in the model will be discussed for each of the components. The intersectoral dependencies of the model will also be reviewed. Chapter III will cover the same material but in more detail. It will use the System Dynamics method to develop the causal effect loops and mathematical relationships that are implemented in the computer program. The present chapter will be limited to a verbal discussion of the modeling of components.

General Focus of the Model

The term “National Park,” in this study, means any area expressly reserved, acquired, controlled or managed primarily for recreation or preservation of the natural environment. Since the purpose of this research is to develop a generic model, the conceptual framework of the model structure is such that it could be used with minor modifications for analyzing any natural resources based regional system.

General Structure of the National Park Region

In constructing a computer model of a National Park system, the selection and arrangement of information about the real system is crucial. The selection of information involves identifying relevant and measurable variables that affect the National Parks Regional Planning process. The arrangement of information involves accurate representation of the relationships among the various information variables. The sources of information and the basis for variable selection and modeling include the relevant literature, existing economic and social development theory, the author's expertise and experts' knowledge and comments.

Key literature resources providing the basis for this study include the groundbreaking work of Jay Forrester regarding industrial dynamics, urban dynamics, and world dynamics. Additional literature utilized extensively to support this study include research by Nathan Forrester, 1973 regarding the modeling of economic development processes using System Dynamics theory. Vital contributions regarding the proper selection of model variables were provided by Joseph Fridgen (Dimensions of Tourism, 1991), and Donald Holecek, from his work regarding a model of the state of Michigan's tourism system. System Dynamics theory applied in this study, particularly in regard to the application of Quantitative System Dynamics approach, also is based on research and teaching by Ralph Levine regarding System Dynamics approaches to planning, forecasting, and analysis for recreational usage. System Dynamics theory pertaining to Qualitative

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Dynamics applied in this study is supported by the work of Peter Senge, as described in *The Fifth Discipline*, 1990. In addition to the author's extensive coursework regarding National Parks planning, resource development, economic development, and general systems theory, he has significant previous experience designing and developing system models, including a coastal community options model used to help simulate the community development decision process (Daniel Talhelm, et al, 1991). A comprehensive list of resources used to develop the National Parks Regional Planning model and this study is provided in the bibliography.

In general , the National Park Regional Model is composed of seven sectors. These sectors are industry, recreation and tourism resources, economic, capital allocation, population, social overhead , and environment. Industry is classified into four basic types: agriculture, manufacturing, mining, and services. In this study, the services sub-sector is divided into household and business services. Only services class is modeled in detail because of its relative importance in the region. The manufacturing and mining sub-sectors are combined into a single sector in the model.

Considered in the tourism and recreation resources sector are tourism and recreation resources, management, infrastructure, superstructure, visitors, and transportation. This sector is the most crucial one in the overall model since it is the central focus in this study. The efficient allocation of scarce recreation resources is the most important means of optimizing economic and social development in the context of this model. In the

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transportation sub-sector, only the roadway system is modeled because of its relative importance in the region (Foresta, 1985).

The economic sector in the model considers wages, incomes, employment, labor force participation and use, tax effects, household service and industrial production, and the region's attractiveness as a place to work, live and/or operate a business.

The capital allocation sector considers the receipt of loans, aid, taxes, and savings which go into a capital pool from which allocations are made to different activities in the region. It is here that trade-offs between allocations to different programs and sectors can be examined in the context of the model yielding insights of great potential value to decision makers.

Population is entered into the system via the following groupings: children, adults and older adults. Rural and urban populations are considered separately. Births, deaths and migration, the three determinants of population change, are modeled. Educational levels, income, health and population programs and practices affect these determinants, and their impact on population change is taken into account. Health service, population programs and practices, and education are modeled in the social overhead sector. The primary, secondary, and tertiary levels of rural and urban education are modeled separately.

The environmental sector considers the trade offs between concern for quality of life and concern for economic growth. Pressure for protecting environmental quality and government action to control pollution contribute to pollution abatement. The main sources

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for the generation of pollution in the model are in the industry and the tourism and recreation sectors.

Specific Sectors

This section will provide a description of the content of each sector as it has been modeled. The major variables used, the physical basis for the model, and the assumptions made in developing the model will be discussed for each sector. These are the sectors that comprise National Park regions. National Park regions may vary in size, geographic location, and other factors, but each region possesses characteristics that can be modeled using these sectors. The characteristics and values of variables within each sector for a typical National Park region may look like the hypothetical region outlined in Table 1.

The Population Sector

The population in the National Park Region is divided into rural and urban, as well as into the following three age groups: children (0-14), adult (15-64), and older adult (over 65). The three determinants of population are births, deaths, and migration.

Births The number of births is obtained by multiplying the number of adults by a birth rate which is assumed to be affected by programs and practices affecting population and by the literacy rate. The rate of these factors is modeled by means of multipliers which are applied to the normal birth rate.

Deaths The death rate is the product of the basic death rate and new births. It is also affected by the status of health facilities which depend upon the relationship between the death rate and the region's hospital bed - population ratio.

Migration The major balancing mechanism tying supply of labor and demand for labor is migration. The rate of migration is related to the difference between the regional unemployment rate and the long-term national unemployment rate. Children and older adult migration is assumed to depend upon the adult migration rate.

Migration from rural to urban areas is attributed to three factors: employment, income, and education. Employment also affects inter-regional migration. If urban per capita income is substantially higher than rural per capita income, there will be higher migration out of the rural area.

The Social Overhead Sector

The social overhead sector in the model describes the social infrastructure in the region. The objective of investment in social infrastructure is to increase the quality of life and the general welfare of society. Both are important components of economic development. The success of social infrastructure development reflects not only the success of economic development, but also the potential to overcome the challenges of endless development problems.

Table 1. Initial Parameter Values Used in the National Park Regional Model

System Variables	Initial Value
Regional Population	2, 964,000 (persons)
Infrastructure Capacity	32,620 (persons/day)
Superstructure Capacity	4,400 (persons/day)
Developed Area	31,000 (acres)
Potential Undeveloped Area	31,000 (acres)
Average annual number of Visitors	3,513,000 (persons/year)
Accumulated load index	0.05
Infrastructure Investment Period	12 Months
Infrastructure Depreciation Period	120 Months
Superstructure Use Rate	20 %
Average Resources Decline Period	60 Months
Per Capita Income	20,000 (dollars)
Average Manpower Adjustment Period	1 Month

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The model considers only health programs and practices affecting population, and education. It is believed that health and education are the most significant indicators of social progress while population programs and practices constitute society's strategy for coping with existing with population problems.

Health Services The number of hospital beds in the region is used to express the state of health services. Its adequacy is represented by the hospital bed to population ratio. The demand for medical personnel is also considered.

Population Programs and Practices The success of programs, policies, and practices that affect population is indicated by the number of Obstetricians and other professionals engaged in this program. The model estimates the demand for population planning personnel based upon the funds available for such programs and activities.

Education The education system in the National Park region includes primary education, intermediate education, secondary education, vocational education, university education, and graduate education. The model, however, considers the education system as an aggregated 3-tier system: primary, secondary, and tertiary. Urban and rural education is treated separately. Student enrollment in any level is increased by new entrants and decreased by graduating students, drop-outs, and migrating students. In computing the literacy rate, the population group which has completed primary education is considered to be literate.

The Economic Sector

The economic sector in the model describes the key indicators of economic development in the region. The model considers employment, wage rate, and per capita income. Employment and wages in manufacturing and services are computed separately. Per capita incomes are determined separately for the urban and rural populations.

Employment Employment in industry and services (including health, population programs and practices, education, tourism and recreation, transportation, and government administration) are computed separately to arrive at total regional employment. Employment in each activity is determined by average labor productivity. A good indicator of economic development that is easily obtained is the fraction of employees in agriculture, mining, manufacturing, and services. Also, the local unemployment ratio is obtained by dividing the difference between available labor force and total employment of the available labor force.

Wages The ratio of regional average wage rate to the national average wage rate, the relative wage rate, depends upon the target relative wage rate and the time to attain it. The target relative wage rate is the eventual relative wage. The target relative wage rate is a function of the average wage rate, the lagged unemployment ratio and the minimum wage rate. The total wages rate is the sum of wages in all employment categories.

Income Per capita rural and urban incomes are determined by dividing industry wages and services wages by their respective populations. For this model, it was assumed that wages are the only source of income, or that other sources are negligible.

Labor Force Participation The labor force is defined as the number of persons 18 years of age or over who are either working or are unemployed (Hall & Taylor, 1991). The labor force participation rate is the percentage of the working-age population that is in the labor force.

Land Use and Tax Effect The term "land use" represents all land use categories in urban areas while in rural areas it represents residential land use only. The model accounts for expansion of the urban area and rural residential land use change which results from the pressure of population growth. The effects of urban land expansion on property values and property tax collections are recognized in the model.

The Tourism and Recreation Resource Sector

In this sector, the development potential of the National Park's resources for recreational activities and the resulting impacts of tourism and recreational development on the local economy have been included. Attendance at recreational sites throughout the region is expressed in terms of visitors and is assumed to be significantly influenced by regional accessibility and the recreational infrastructure and superstructure capacities. The definitions of infrastructure and superstructure are explored in detail below.

Tourism and Recreation Resources The function of the tourism and recreation sector in this study can be viewed as the process of making the raw materials (i.e. natural resources) into products (i.e. tourism and recreation resources). Tourism and recreation resources are the main reasons why visitors access the National Park region. The development of potential natural resources into valuable tourism and recreation resources is crucial for economic development in the National Park region. However, tourism and recreation resources are not infinite. Thus, the allocation and sound management of developed resources are key elements to maintain the use of the resources at a useful and lasting level. However, the development and use of resources often conflicts with the need to protect the long-term use of the resources. For this reason, it is necessary to establish a development standard. The standard is called “carrying capacity,” or the capacity to maintain development and use of a particular resource over the long run.

Infrastructure Attractions and facilities are not accessible to tourists until infrastructure needs have been met (Mill & Morison, 1985). The infrastructural sub-sector of a National Park region is taken here to include physical elements such as communication networks, water supply, electric power, and housing. All of these physical elements are combined to create an infrastructure capacity element for the purpose of modeling the infrastructure sub-sector of the model. Infrastructure capacity is defined as the capacity of infrastructural facilities to serve a set number of visitors during a specifically period of time.

Superstructure Superstructure is not a necessary condition for developing a tourism and recreation area, but it is a positive contributor to an area's attractiveness as a travel destination. In general, the superstructure includes lodgings, restaurants and recreation facilities, etc. (Fridgen, 1990). Superstructure attractiveness is not only measured by capacity, but also by the level of services available. Large capacity is but one measure of the attractiveness of the recreation sub-sector. Visitors' satisfaction with the level of services also contributes to overall attractiveness of the recreation sub-sector. In this study, the concept of level of services is indicated by a special relationship between service quality and superstructure capacity.

Visitors The number of visitors was selected as the measure of the performance of the recreation sub-system. However, an increasing number of visitors alone does not indicate better performance of the recreation sub-sector. In the short run, excess visitors would destroy recreation resources and create a barrier to resource development in the long run. Offering high quality service to increasing numbers of visitors, without reducing future resource development possibilities, is an important responsibility of National Park region managers.

Manpower Management In relation to the tourism and recreation resources sub-sector, the main duty of National Park managers is to develop new resources and maintain existing developed resources. Thus, manpower in this model includes technology manpower and management manpower. Technology manpower includes manpower

necessary for the development of new resources. Management manpower includes manpower necessary for the maintenance of existing developed resources.

Transportation Transportation is one of the most important recreational infrastructural elements in the regional development process. In the transportation sub-sector, only the roadway system is modeled because of its relative importance to the region. The road network in the region is classified into highway and feeder roads. The road inventory is increased by new construction. Reduction of road inventory is not permitted in the model because it is assumed that all roads will be at least minimally maintained as needed to accommodate expected traffic. The construction rate depends on available funds for construction, unit costs, and construction delays. The demand for transportation services is determined from considerations of recreational and industrial use.

The Environmental Sector

The environmental sector of the planning model considers problems related to the industrial and tourism/recreation sector's generation of pollution as well as the natural occurrence and reduction of pollution and their affect on the availability of resources for development. To decrease the generation of pollution, government must regulate firms and visitors discharging pollutants exceeding acceptable levels. Thus, in this sector the pollution index, the number of people concerned with environment quality, the number of people concerned with economic growth, and the investment in pollution abatement by

government and private firms are indicators which represent the trade-offs between quality of life and economic development in the region.

The Capital Allocation Sector

The allocation of scarce capital resources to competing activities in the region is of paramount importance in striving to achieve economic and social development in the National Park region.

Capital Pool In the model, all external loans, public and private savings, and internal loan repayments accumulate in a variable called the capital pool. Government savings are the excess of incomes over expenses. Government income is obtained through taxation on personal incomes, regional production (e.g. industry, and tourism and recreation), and real property and land holdings.

Capital Allocation Available capital is allocated to two major classes of activities: tourism and recreation, and social overhead. The allocations are shown as constant fractions of the capital which can be varied to test the trade-offs between capital allocation to different activities. The social overhead allocation is further distributed to education, health, and population programs and practices. The activities in the model which compete for capital with tourism and recreation development are infrastructure and superstructure development needs.

Intersector Dependencies

In Figure 1, seven sectors of the model are displayed: [1] Tourism and Recreation Resources; [2] Capital Allocation; [3] Economic; [4] Industry and Services; [5] Population; [6] Social Overhead; and [7] Environmental. Each sector has a function in regional development, and the sectors fit together in a structural network.

It is evident that policies adopted in one sector will influence all other sectors either directly or indirectly, and hence, it is necessary to consider all of them in a comprehensive model. The complete discussion of the conceptual model and the emphasis of the System Dynamics model will be introduced in Chapter III, where the core of the integrative model is completed.

The Modeling Approach

Brief Review of the System Modeling Approach

Models are a rational attempt to describe the relationships between the variables entering into a problem. Models are particularly important when the system to be studied is complex or inaccessible. The use of models in planning for regional development can be justified because: [1] regional development planning involves complex technological, economic and social considerations, and [2] such planning deals with the future which, because of uncertainty, is inaccessible.

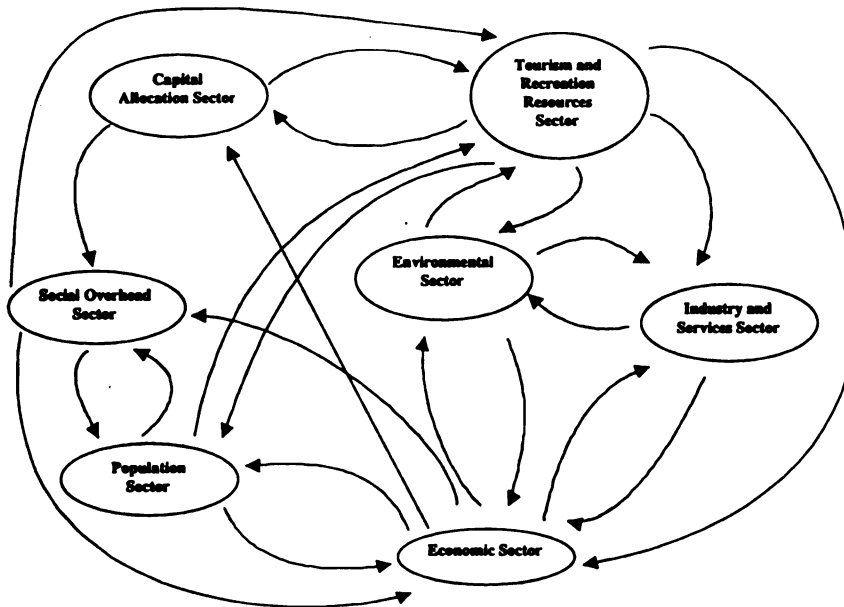


Figure 1. Inter-sector Dependencies in the National Park Regional Model

Modeling in planning consists of the use of either sub-models or system-wide models. Limitations in the modeling of regional problems in the past have tended to lead to the construction of sub-models with outputs from one being used as the inputs to another, rather than trying to deal with all aspects of the system simultaneously, as with the use of a system-wide model.

The simplest attempt at system-wide modeling in the planning process is mathematical programming. The general mathematical programming model strives to facilitate the selection of an optimal growth pattern for future development by determining

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the investment mix which optimizes some criteria (e.g. minimizes total cost). The problem with this approach when applied to multi-sectoral regional analysis is that, because of the need for simplifying assumptions, little realism is achieved.

Although explicit quantitative techniques are preferable to the non-quantitative methods of regional analysis, the former have suffered as in the case of mathematical programming because of the need to alter the problem to fit the procedure. Of all the quantitative methods available, simulation places the least restrictions on problem representation. Therefore, simulation offers the most promise as a tool for allowing the planner to act out in the computer laboratory the behavior of a complex regional system under varying conditions. Through simulation, the planner can observe directly the potential effects of policy changes, alternative planning strategies, or new development programs.

The conventional system wide simulation approach is a kind of event simulation. It reproduces the microstructure of the system being simulated in the model. To try to apply this type of simulation to a region and still consider all the major sectors would be prohibitive. Essentially, conventional system wide simulation models are equilibrium analysis models. Equilibrium assumes that there exists a balance or stability between the inputs and outputs and that a "prediction" merely involves the specification of the inputs at the assigned point in time. The models are essentially a temporal device because they do not consider the process of moving from one situation to another and because the length of

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time required for the system to adjust to the new inputs remains unspecified. In other words, this type of event simulation or comparative-static approach has some obvious disadvantages in a planning context. First, it is an incorrect simulation of the historical process of development. Secondly, the whole focus of policy testing is on marginal change. Lastly, it is impossible to study the phasing of the effects of policies through time.

System Dynamics

The field of System Dynamics began with the founding of the Sloan School of Management at Massachusetts Institute of Technology by Jay W. Forrester in 1956. System Dynamics is a way of analyzing the behavior of complex systems to show how systems are structured and how policies used in decision making govern the behavior of the system. "Structure" in this context is defined to include the components of the system and the communication channels by which information is made available at decision-making points. "Policies" is defined as the rationale that influences how decisions are reached such as natural-generating processes, experience, laws, rules of thumb, etc. System Dynamics modeling strives to express, in the form of causal feedback loops and mathematical equations, the structure of the system upon which policy acts.

In essence, five characteristics of the System Dynamics method arise from its holistic view and wide applicability. The five characteristics are as follows:

1. **System Thinking.** The methodology of System Dynamics is based on a philosophy that views a problem globally, i.e., from the broadest possible perspective. The

problem can be either one of design of a new system or of control of an existing system. To design a new system or to control an existing system can help the designer, planner, manager, and the ultimate user have the opportunity to study developing goals, confirm the components, and understand the sub-system interrelationships, as well as decide control options.

2. **Information Feedback Control Theory.** Real world systems are usually characterized by circular causality. The feedback loops represent the transmitting, the dynamic behavior of one attribute to the next until the circle is closed and the signal, in a modified form, is fed back to its origin. Such loops have a tendency to stabilize or to destabilize a system. When system planners try to manage a feedback system, their actions are typically amplified or counteracted, depending upon which feedback structures are dominating the system at the time.
3. **Delay Concepts.** The emphasis on understanding the impacts of lag and delays in a system is one of the important characteristics of System Dynamics. How long something takes to occur can profoundly impact the overall behavior of a system (Levine & Fitzgerald, 1992). Delays are an ubiquitous feature of dynamic systems; they are present at every stage of an action. Time is required to recognize a problem, to decide what to do about it, and to implement action once a decision is made. Many decisions turn out to be faulty because people underestimate the length of delays.

Thus, policy-makers and planners must understand delays if they are to predict the consequences of their actions.

4. **Simulation and Gaming.** Simulation is one of the most powerful techniques available for solving a problem. It involves the construction of a replica or model of the problem on which researchers experiment and test alternative courses of action. Operational games based on System Dynamics models have been used in System Dynamics teaching since the beginning (Meadows, 1989). Hence, the latest trend in using computers to simulate dynamic systems is to develop user oriented system dynamics-based games. With this gaming package, decision makers who will eventually be using the model as a policy aid can participate in the modeling process right on the computer screen. Also, the educator can adopt the gaming simulation model as a classroom laboratory to teach and experiment with human behavior (Richmond, 1987).
5. **Computer Technology.** Following the previous point, computers play an important role in building a System Dynamics simulation model. Computers enable researchers to handle complex non-linear relationships and to model the system realistically from the start. Computer technology allows users to modify parameters quite quickly to see what would happen under changing conditions. Advances in computer and software technology continue to create easy to use and graphical gaming interfaces.

The application of these advanced gaming interfaces enables users to interact directly with system models with little or no prior training (Anderson & Richardson, 1990).

Rationale for Selecting the System Dynamics Method

The modeling approach to be selected for any analysis should depend upon the problem to be investigated and the purpose of the study. In the previous section, the characteristics of System Dynamics as a modeling approach were explored in the previous section. Several reasons for selecting the System Dynamics approach for this research are discussed below:

1. National Park regions are complex. National Park regions are complex systems involving demographic, economic, social, natural resources, environment, and tourism and recreation elements. Complex regional systems are systems of high-order, multiple-loop, non-linear feedback structure, and have delays or lags. Non-linearity implies that system attributes influence each other in a non-proportional way and that they interact so that their partial effects, playing out over time, cannot easily be distinguished. Such interactions may cause shifts in the structural dominance of a system over time. That is, substructures that have dominated a system's behavior for some time may, suddenly or gradually, lose their influence while other substructures gain influence. This typically causes dramatic modification of the system's dynamic behavior. Delays distribute the effects of changes in variables throughout a system over time and often cause information to arrive at its destination in an untimely, and

hence, harmful manner. Delays and lags lead researchers to discover and give priority to short-run gains and to ignore and postpone actions against future losses. Dynamic simulation is a means to understand how complex geographical regions evolve and change through time.

2. The feedback nature of development problems. The regional development process, like many processes in the world of nature and society, involves several variables mutually affecting each other so as to form causal effect loops. Feedback loops exhibit behavior that can only be analyzed by studying the complete system; analyzing the separate components of the loop in isolation from one another does not even hint at the sorts of behavior that might arise.
3. Regional planning is a circular process and strongly depends upon feedback. The planner should be in a position to match changes in the system structure by altering the planning trajectory as well as by adjusting operating policies. The relevant models for planning are therefore unlikely to come from the processes behind the construction of physical artifacts or physical planning, but rather from their management which consists of those activities or sciences concerned with the management of feedback systems.
4. Economic development is a multifaceted issue. Any economic development program is judged by its ability to create jobs, promote economic stability, increase property values and expand opportunities to achieve "quality of life." Many factors must be

included in a system to develop an economic development action plan, and any one of them can spell success or failure to economic development. System Dynamics lends itself well to the "options-open" adaptive strategy for accomplishing the economic development action plan as well as a framework to act as a guide in the plan's development.

5. The inadequacy of data in regional analysis is due to poor information bases and rapid changes. Application of dynamic simulation to a National Park region is beginning to expose the myth that the first step in planning must be the extensive collection of vast amounts of statistical data whose value does not equal a fraction of the cost. A realistic system wide model should come first to determine what data should be collected.

Review of Previous Research

While there is a considerable amount of general literature which separately deals with urban planning, physical system design and economic development policy design, there is little literature on the simultaneous determination of the economic development plan and tourism and recreation resources, demographic considerations, and the environment in one paradigm. This section will present a brief description of the previous models which are related to this study; gaming simulation models built using the System Dynamics method are included.

Initial application of the System Dynamics mechanism to social behavior was developed in Jay W. Forrester's first book (1961). Forrester first called his approach to system analysis Industrial Dynamics, but it was later re-named System Dynamics (Levine & Fitzgerald, 1992). An Industrial Dynamics study covers the production, distribution, and retailing of a commodity in order to interrelate all the components (i.e., men, materials, money, orders, equipment and information), of a business system. The approach is one of building models of companies and industries to determine how organizational structural, amplification (in policies) and time delay (in decisions and action) interact to influence the success of the enterprise. An Industrial Dynamics simulation aims to demonstrate the characteristic behavior of the system rather than to predict specific events. The result is a "management laboratory" in which proposed changes in organizational structure or policy can be tested and the results used as a guide to better management.

Jay W. Forrester (1969) published the book Urban Dynamics, which extended the System Dynamics approach to describing the growth and stagnation characteristics of urban areas. This study simulates the life cycle of an American city over a 250-year period by examining three systems: business enterprises, housing, and labor forces. Each of these systems contains three classes: business enterprise consists of new enterprises, mature business, and declining industry; housing comprises premium housing, worker housing, and underemployed housing; the labor force consists of managerial-professional

workers, labor, and underemployed persons. Then, the life cycle of an urban area is generated by the simulation model and shows how growth gives way to maturity and then stagnation. The urban area is a complex, self-regulating system that creates internal pressures to modify economic activity and shift the uses of land, structures, and people. These changes are dominated by the construction, aging, and demolition of industry and housing combined with concurrent population movements. Forrester draws several general conclusions: complex systems are counter-intuitive and are strongly resistant to most policy changes but highly influenced by some if they can be found. Moreover, the short-term response to a policy change in a complex system is often in the opposite direction from the long-term effect.

Hamilton, et al. (1969) couples an economic model for a river basin with a model of the water sector treating demand, cost, quality, quantity, and the like. It is the first regional simulation model employing the System Dynamics technique. The model not only ties the demographic, economic, and water sector together, but also incorporates important dynamic elements (delay, feedback, accumulation, etc.). The three main elements of the model are: [1] the demographic sector, [2] industry (employment), and [3] water supply. In addition, there are submodels for recreation, income and electric power requirements.

Dennis L. Meadows (1970) published his first book on System Dynamics in 1970 titled Dynamics of Commodity Production Cycles. He criticized the classical cobweb

theorem and some of its modifications which he claims cannot represent the dynamic relationships in actual commodity systems adequately. Employing System Dynamics methodology, Meadows develops a general dynamic model considering the economic, biological, technological, and psychological factors which lead to the instability of commodity systems.

Jay W. Forrester (1971) published another distinguished System Dynamics application book, World Dynamics, which offered a dynamic model of world scope. His objective was clearly to illustrate a more rational, more analytical and more thorough analysis of the factors which combine to produce a “quality of life.” Five levels were chosen as the cornerstones on which to build the world system structure: [1] population, [2] capital investment, [3] natural resources, [4] fraction of capital devoted to agriculture, and [5] pollution. The computer model interconnects concepts from demography, economics, agriculture, and technology. From these five levels and their interactions appear to come the dynamics of changes in the world system. Rising population creates pressures to increase industrialization, grow more food, and occupy more land. But more food, material goods, and land tend to encourage and permit larger populations. However, in time, growth encounters limits set by nature. Land and natural resources become exhausted and the pollution-dissipation capacity of the earth becomes overloaded. The model describes a world system that shows a variety of alternative

behaviors. Which behavior is the most likely scenario for the future depends on policies that man may still be able to choose.

Nathan B. Forrester (1972) extended the application of the System Dynamics methodology to economic development on a national level with the publishing of the book titled The Life Cycle of Economic Development. In this model, economic activity is divided into five production sectors -- agriculture, goods, services, capital, and resources. Each sector has a functional niche in the economy, and the sectors fit together in a structural network. The model deals with the shifting allocation of labor and capital between major production sectors to balance the needs of capital accumulation which is controlled by the relative marginal productivity of capital and labor. Various possible strategies of economic development are analyzed. Therefore, the model serves in effect as a laboratory for policy experimentation.

Nathaniel J. Mass (1975) developed a sequence of System Dynamics models to analyze and explore the economic processes underlying short-term and long-term business-cycle behavior. Business cycles are recurring fluctuations in total production, wages, price, employment, inventories, and capital investment. Such fluctuations have been observed and charted in the United States for over one hundred years. In general, Mass's model overviews existing theories of the economic cycle and provides a general framework for evaluating the impact of social and economic factors on economic cycles of various periodicities.

Alfeld and Graham (1976) published the book, Introduction to Urban Dynamics, which provides a step-by-step approach to understanding the ideas and concepts introduced in urban dynamics. It explains the complexity of the urban system by examining simpler urban subsystems one at a time. The book contains eleven urban models. Each model is slightly more complex and realistic than the one before it. This book illustrates some principles of urban behavior, and discusses each model in terms of real events and policy issues. Land use, attractiveness, and aging and obsolescence are three major concepts of urban dynamics. They provide a framework to view the behavior of the entire city.

SimCity (1989) is a computer entertainment game. The underlying structure of this game is a system simulation. Although the principal purpose of this type of game is to build a “dream city” for the players’ challenge and amusement, its concepts of simulation and scenario planning for a city have been employed for some educational uses. It provides the players with a set of rules and tools that describe, create and control a city system. The challenge of playing this game is to figure out how the system works and take control. As master of the city system, the player is free to use tools to create and control a city within the framework and limits provided by the rules. The rules are based on city planning and management variables, including human factors, economic factors, survival factors, and political factors. The tools provide the player with the ability to plan, lay out, build, bulldoze, re-zone, and manage a city.

SimCity is designed primarily as a game and not as an educational tool, and players are exposed only to processes of allocating and managing resources and relative system components. The game does not expose users to the qualitative issues related to building, designing, and analyzing a system. Therefore, SimCity has limited educational and academic utility.

In his book, The Fifth Discipline (1990), Peter M. Senge extends the applications of Qualitative System Dynamics methodology to help understand the organization of the social phenomena. In this book, Senge suggests that several learning disabilities result when learners continually apply trial and error methods. Attempting to understand the future by relying on the past only forces the learners to try and solve the same problems. However, the primary threats to learners' survival today come not from events, but from gradual processes to which most people are blind. The author offers causal feedback training methods to help learners avoid these learning pitfalls. This book furnishes a good picture of Qualitative System Dynamics thinking for empirical studies.

Meadows, Fiddaman and Shannon (1993) developed a micro-computer game named Fish Bank, an assisted group simulation that teaches principles of sustainable management of renewable resources while illustrating the interaction of economics, biology, and group behavior. System Dynamics methods were used to design the computer model, which was proposed as an operational gaming tool.

The Modeling Process

Figure 2 is a flow chart describing the modeling process. The process is carefully designed to divide a larger problem into more manageable components that can be described in causal feedback loops. In conjunction with the appropriate computer program, these feedback loops can be utilized to develop a system structural model and a model evaluation strategy to facilitate effective model use.

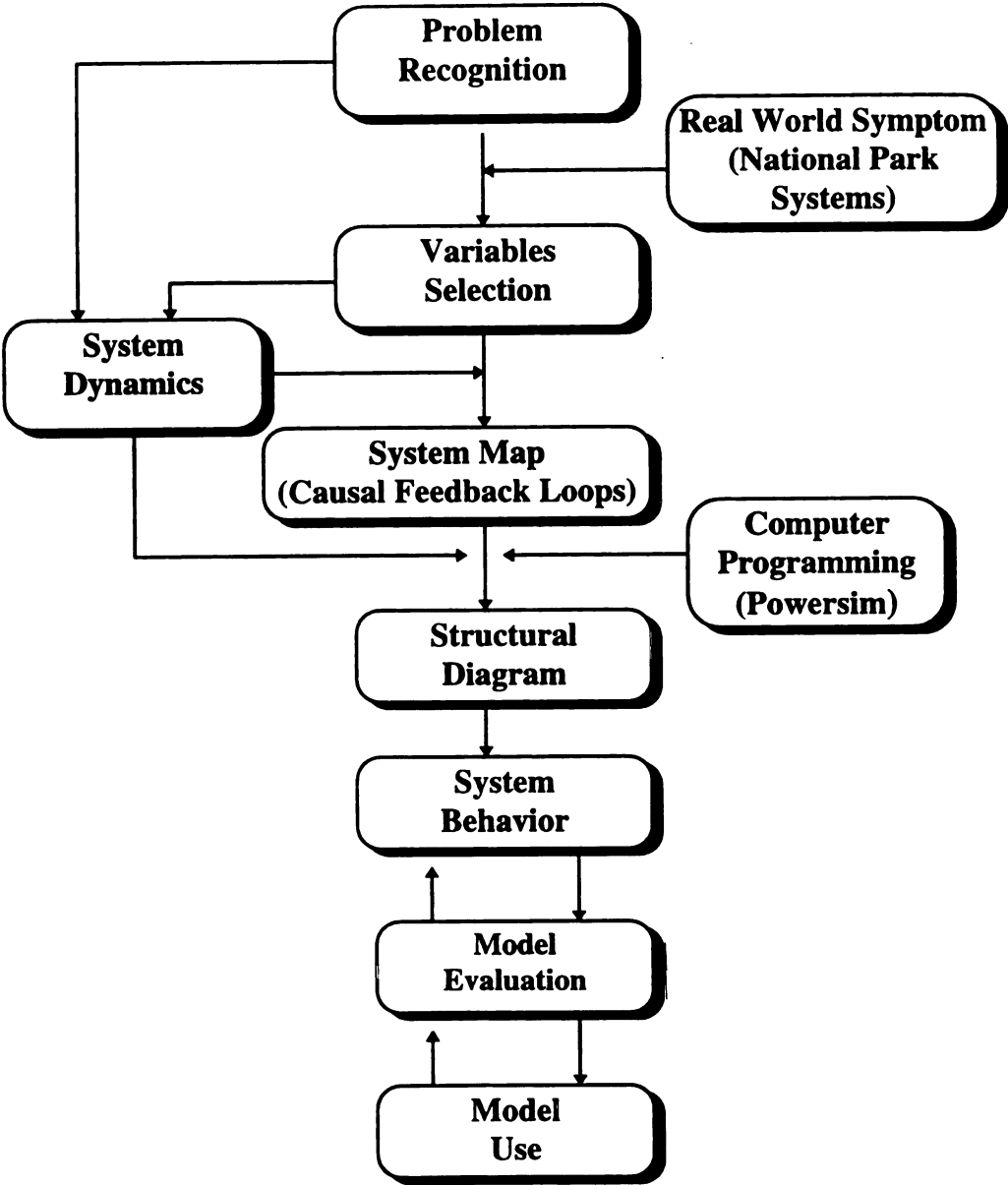


Figure 2. The Processes of the System Dynamics Modeling

CHAPTER III

FORMULATION OF THE MODEL

Introduction

The System Dynamics method used in this study is comprised of two separate phases which are referred to as Qualitative and Quantitative System Dynamics (Wolstenholme, 1990; Levine & Fitzgerald, 1992). Figure 3 shows a summary of the steps involved in these two methods and their purposes. The Qualitative System Dynamics phase is based on creating cause and effect diagrams according to precise and rigorous rules and using these to explore and analyze the system. The Quantitative System Dynamics phase involves representing quantifiable relationships between the causal variables involved. In it, a set of simulation difference equations are written and then used for experiments.

This chapter begins with a discussion of Qualitative System Dynamics using the causal-effect diagram to describe the interrelationships of the variables in this study. Next, the model used is presented in quantitative terms. However, for the purpose of keeping the presentation manageable, modeling will be kept simple, and sophisticated discussions of calibration techniques will be avoided.

Qualitative System Dynamics	Quantitative System Dynamic		
(Diagram construction and analysis phase)	(Simulation phase)		
	stage 1	stage 2	
	Create and examine feedback loop structure of system using resource flows, represented by level and rate variables and information flows, represented by auxiliary variables.	Examine the quantitative behavior of all system variables over time. Examine the validity and sensitivity of system behavior to change (1) information structure (2) strategies (3) delays/uncertainties	Design alternative system structures and control strategies based on (1) intuitive ideas (2) control theory analogies (3) control theory algorithms in terms of non-optimizing robust policy design. Optimize the behavior of specific system variables.
	Provide a qualitative assessment of the relationship between system processes (including delays), information, organizational boundaries and strategy.		
Estimate system behavior and postulate strategy design changes to improve behavior.			

Figure 3. System Dynamics --- an overview of the process

Source: Wolstenholme, 1990

Having provided an overview of the model, its various components will be examined in detail. Considerable attention will be given to some of the subtle elements of the model as well as to methods actually used to quantify the key inputs to the model.

Qualitative System Dynamics

The major use of a qualitative System Dynamics diagram is to identify information feedback loops which have been created by linking resource and information flows. It is the analysis of such loops which facilitates understanding of how the processes, organizational boundaries, delays, information, and strategies of systems interact to create system behavior. A causal feedback loop consists of two or more variables that close back on themselves. The sign "S" identifies changes in the same direction. The sign "O" identifies changes in the opposite direction¹. In other words, if any variable in an "S" loop changes, then the loop causes that variable to change even more in the same direction. If any variable in an "O" loop changes, then the loop causes that variable to correct itself and to readjust in the opposite direction. There are two kinds of feedback loops: reinforcing and balancing. Reinforcing loops create exponential growth, while balancing loops are self-regulating and bring the system towards

¹ Some academic research uses the "+" and "-" to represent the causal direction. However, it is easy to confuse these signs as "good" or "bad" impacts. Thus, this study adopts the "S"(change same direction) and "O"(change opposite direction) to display the variables' causal direction since change in either direction can be either good or bad in their impacts.

equilibrium when they dominate. The sign of a causal feedback loop is obtained by counting the number of “O” causal relationships around the loop. If there is an odd number of “O” causal relationships, the loop is a balancing feedback loop; if there is an even number, the variables are connected by a reinforcing feedback loop. Figure 4. exhibits a comprehensive picture of the causal feedback loops of the National Parks regional system. The arrows indicate the direction of causation. The symbols used in the causal feedback loops are summarized in Figure 5. The following is a description of each feedback loop identified in the diagram.

Causal Feedback Loops

Infrastructure Capacity - Infrastructure Investment Loop

The three feedback loops in Figure 6 communicate with each other through infrastructure capacity. As visitors increase, infrastructure congestion goes up; this tends to decrease regional accessibility. If infrastructure capacity congestion achieves a certain level, the manager must make the decision to invest in new infrastructure according to the infrastructure investment criteria; then, infrastructure capacity will increase. This is a balancing loop which is described in loop 1 (infrastructure capacity - infrastructure

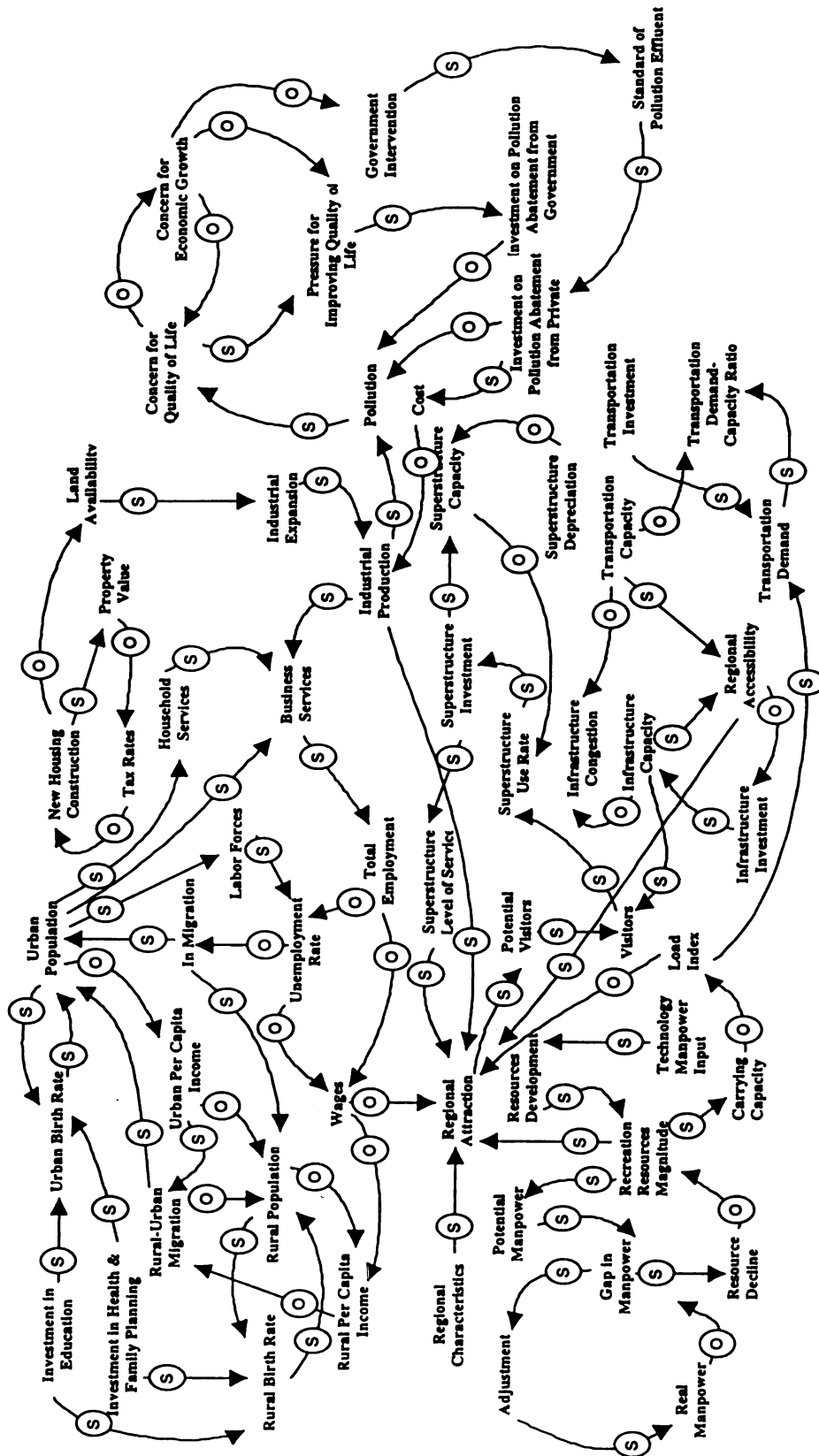


Figure 4. A Conceptual Causal Effect Diagram of the System Model

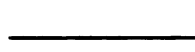
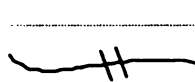
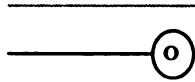
 and/or B# Balancing Loop	The surrounding causal loop is a Balancing loop, possibly identified by a number.
 and/or R# Reinforcing Loop	The surrounding causal loop is a Reinforcing loop, possibly identified by a number.
 Influence	An arrow represents a causal link from one variable to another. The arrow's label signifies whether the variable at the arrow tail will influence the variable at the arrow head positively (S) or negatively (O).
 Delayed Influence	A double line across the link signifies that the influence is significantly delayed.
 Change in the Same Direction	Given that all other influences are constant, a change in the variable at the arrow tail will change the variable at the arrow head in the Same direction.
 Change in the Opposite Direction	Given that all other influences are constant, a change in the variable at the arrow tail will change the variable at the arrow head in the Opposite direction.

Figure 5. The Symbols in the Causal Effect Diagram

Source: Powersim User's Guide and Reference, 1993

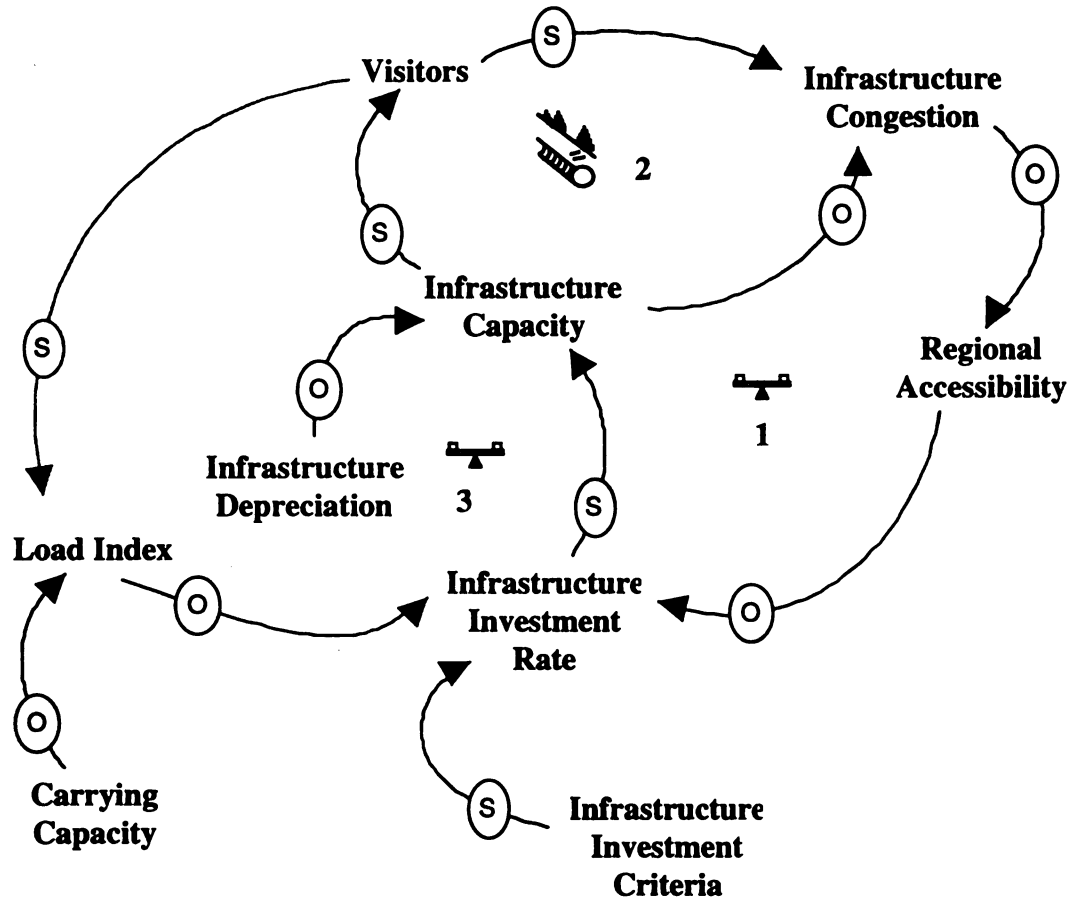


Figure 6. Infrastructure Capacity - Infrastructure Investment Loop

congestion - regional accessibility - infrastructure investment rate - infrastructure capacity).

As a matter of fact, the decision to invest in infrastructure is not only a response to congestion, but also a response to load index. In loop 3, load index has an opposite impact on infrastructure investment. When the infrastructure capacity goes up, visitors will increase. An increase in visitors will cause the load index to increase. At the same time, in loop 1 the infrastructure capacity increase will allow the regional accessibility index to go up. In other words, the load index and regional accessibility index will increase simultaneously. This means that the two indexes must be considered in the feedback of the investment policy and decision. The causal feedback loops are exhibited in the balancing loop 3 (load index - infrastructure investment rate - infrastructure capacity - visitors - load index) and reinforcing loop 2 (visitors - infrastructure congestion - regional accessibility - infrastructure investment rate - infrastructure capacity - visitors).

Superstructure Capacity - Superstructure Investment Loop

Actually, there are two loops coupled together in Figure 7. High quality level of service makes a positive contribution to regional attractiveness. When the regional index goes up, visitor numbers will increase. An increase in visitors will increase the superstructure use

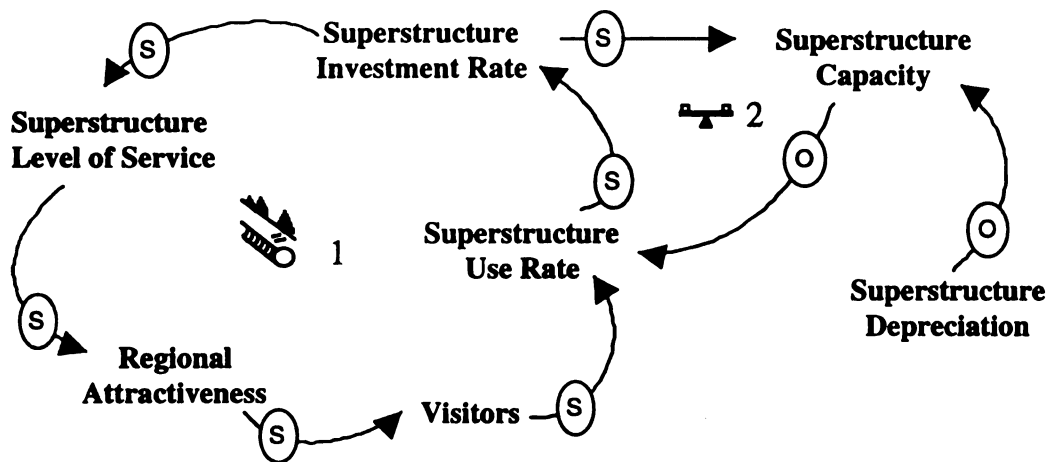


Figure 7. Superstructure Capacity - Investment Loop

rate (i.e. visitors/superstructure capacity). Therefore, an increase in the use rate will stimulate investment and promote the construction of superstructure. This feedback behavior is exhibited in reinforcing loop 1. In the balancing loop 2 (superstructure use rate - superstructure investment rate - superstructure capacity - superstructure use rate), it is demonstrated that an increase in the superstructure use rate will result in an increase in superstructure capacity. However, an increase in superstructure capacity has an opposite impact on superstructure use rate.

Manpower Management - Resources Magnitude Loop

The manpower management sub-sector is displayed in Figure 8. As mentioned in Chapter II, manpower in the National Park region can be divided into two categories: technology and management manpower. Technology manpower includes manpower necessary for the development of new resources. Management manpower includes manpower necessary for the maintenance of existing developed resources.

Management manpower is a variable that is based on seasonal adjustments. Management manpower, therefore, becomes a controllable variable. The magnitude of recreation resources to be managed determines the level of potential maintenance employment. If there is a gap between potential management manpower and real management manpower, then recreation resources will begin to decline. This relationship is reflected in balancing loop 1 (resources magnitude - potential maintenance employment - gap - resource decline - resource magnitude). As shown in balancing loop 2 (real maintenance employment - gap - adjustment - real maintenance employment), when a gap occurs, the manager must adjust real maintenance employment in order to reduce the gap.

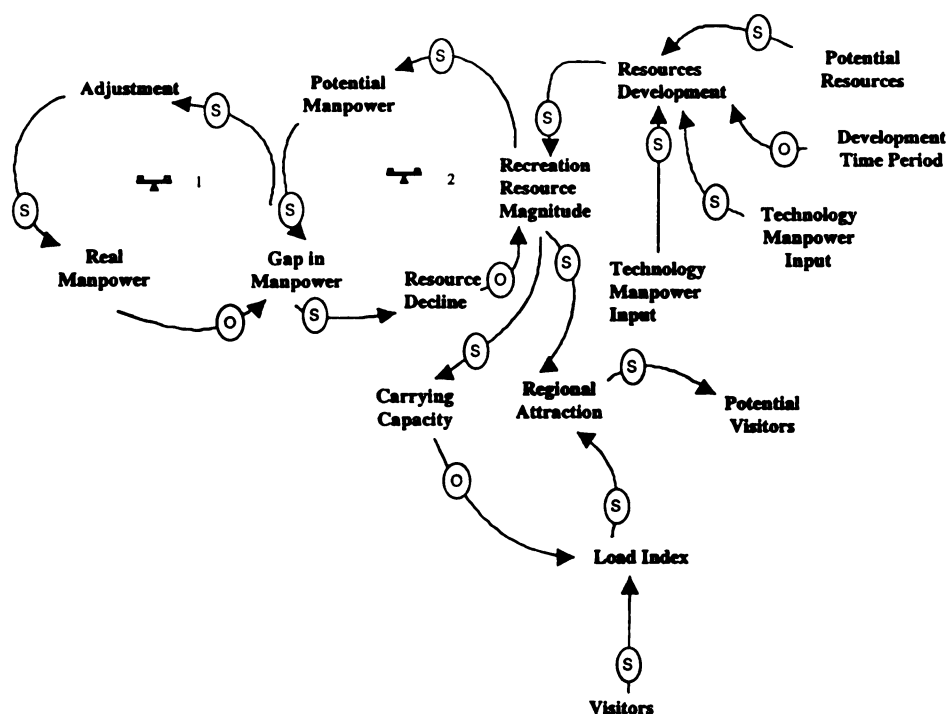


Figure 8. Manpower Management - Resource Magnitude Loop

Another relationship between the magnitude of tourism and recreation resources and resources maintenance and development is demonstrated in this loop. The magnitude of tourism and recreational resources will increase due to tourism and recreation resources development. Unless the developed resources are well maintained, they will decline gradually. The larger the magnitude of recreational resources, the more attractive the region to visitors. An increase in the magnitude of recreational resources will

increase the carrying capacity. By dividing the number of current visitors by the carrying capacity, the load index can be calculated (current visitors / carrying capacity).

Visitor - Attractiveness - Load Index Loop

The feedback loop illustrated in Figure 9 indicates the relationship of visitors, attractiveness, and infrastructure capacities. In this model, the basic assumption is that regional attractiveness is the indicator which reflects the potential number of visitors who would like to access this region. If infrastructure capacity is available, then potential visitors will become real visitors to the region. Also, note that regional attractiveness depends upon both resource magnitude and load index in the loop. In summary, this balancing loop demonstrates that when infrastructure capacity increases, the number of visitors and the load index increase. This causal feedback is demonstrated, therefore, when the regional index decreases and potential visitors declines.

Transportation Capacity - Demand/Capacity Ratio Loop

As transportation capacity increases, due to investment in transportation or other related variables, the demand-capacity ratio falls. Inadequate investment in transportation, therefore, may result in a transportation shortage. A lower transportation capacity, on the other hand, results in more funds being diverted to transportation. This

loop, which is shown in Figure 10, will not let capacity overshoot demand. This is a balancing loop controlling investment in transportation.

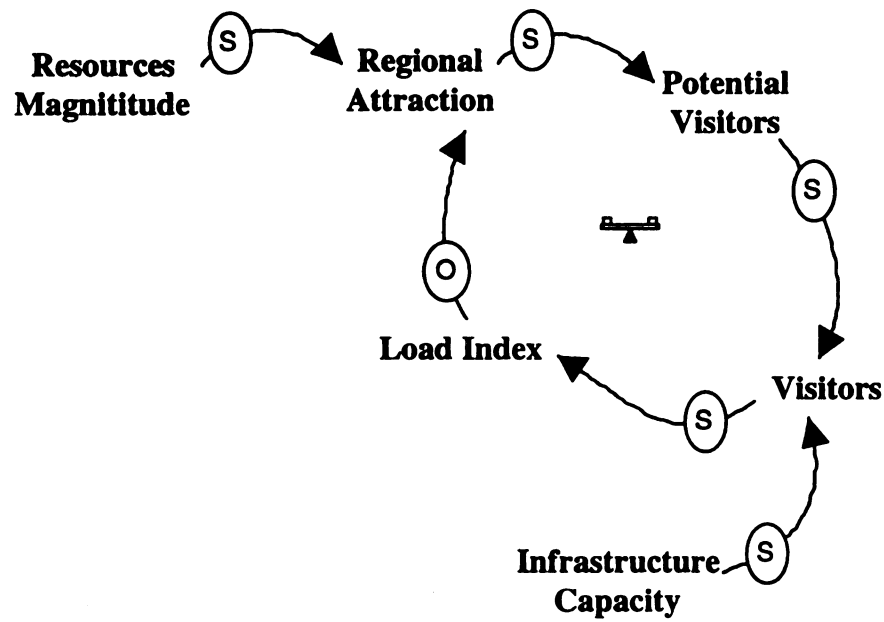


Figure 9. Visitor - Attractiveness - Load Index Loop

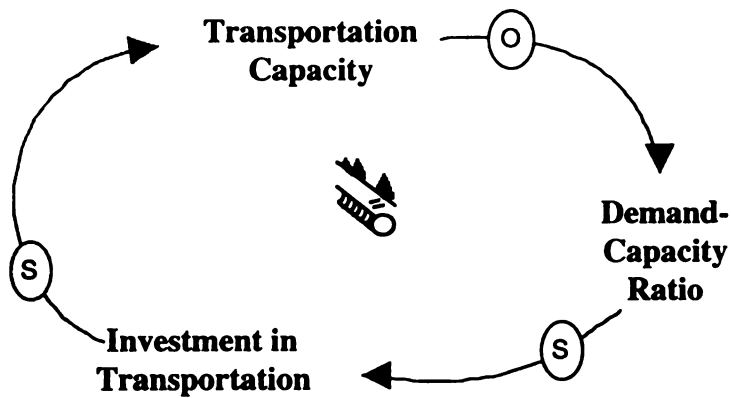


Figure 10. Transportation Capacity - Demand/Capacity Loop

Rural Population - Per Capita Income - Rural-Urban Migration Loop

This balancing loop controls the growth of rural population. An increase in population will decrease per capita income, which then induces the population to migrate to the urban area. This migration keeps the population rise in check in the region of the park. The structure of this loop is shown in Figure 11.

Population - Net Birth Loop

A traditional, reinforcing growth process is demonstrated in Figure 12. This loop shows that population influences net births per year (births minus deaths) which, in turn, influences population.

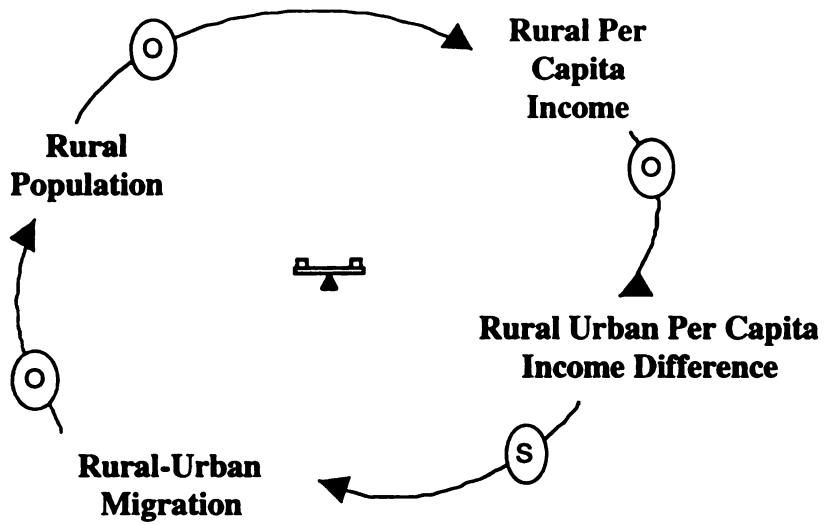


Figure 11. Rural Population -Income - Migration Loop

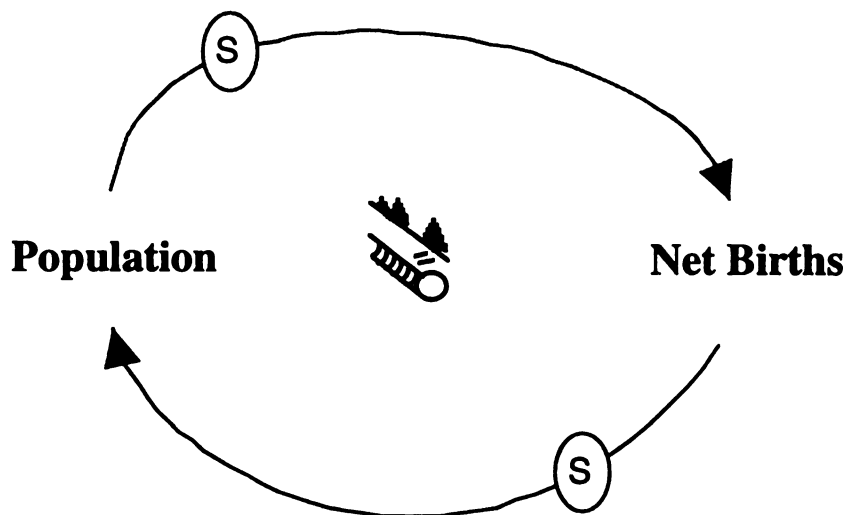


Figure 12. Population - Net Births Loop

Population - Labor Force - Unemployment - Migration Loop

An increase in population implies a large labor force which results in a higher unemployment rate assuming that at some point population growth overcomes the economy's job creating potential. This encourages out-migration of the population. This loop is illustrated in Figure 13.

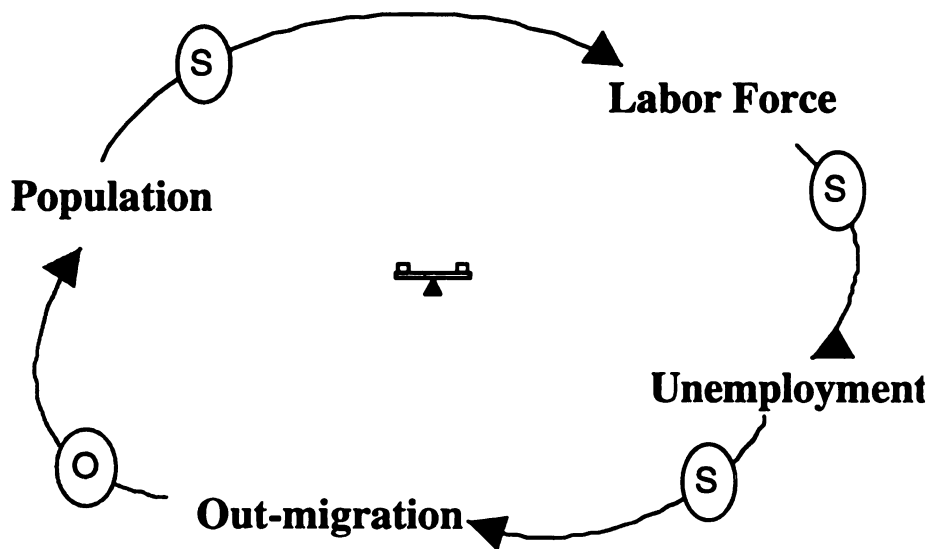


Figure 13. Population - Labor Force - Unemployment - Migration Loop

Wages - Regional Attractiveness - Industry Production - Employment Loop

Industrial production and employment changes in the same direction. An increase in industrial output requires more labor, thus employment increases. An increase in employment (lower unemployment rate) results in higher wages as it becomes increasingly difficult to find labor which stimulates large increases in wages. Higher wages reduce the region's attractiveness for new businesses or expansion of existing businesses. As regional attractiveness decreases, capital investment in industry declines and thus industrial output is constrained. The structure of this loop is shown in Figure 14.

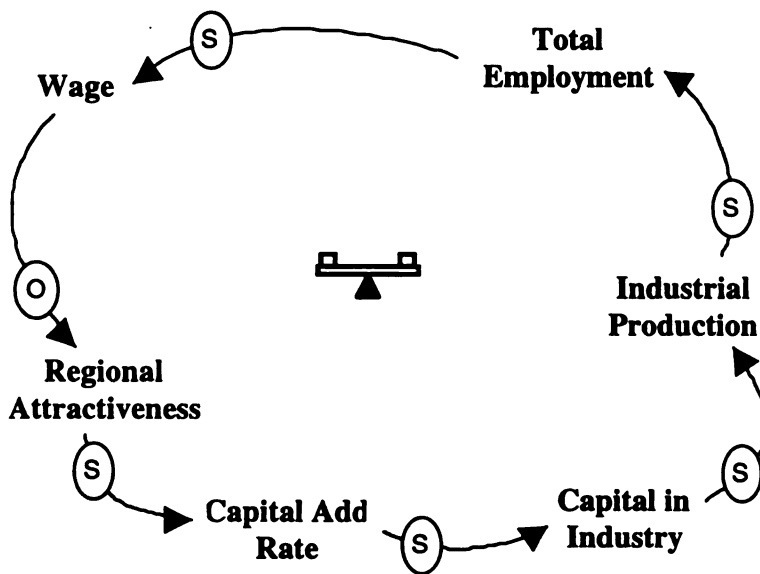


Figure 14. Wage Rate- Regional Attractiveness -Employment Loop

Health Services- Deaths - Population Loop

The extent of health services in the region can be expressed in terms of the hospital bed-population ratio. Increasing this ratio leads to a reduction in the death rate which results in the increasing of population and, therefore, the hospital bed-population ratio is decreased. The Structure of the loop is shown in Figure 15.

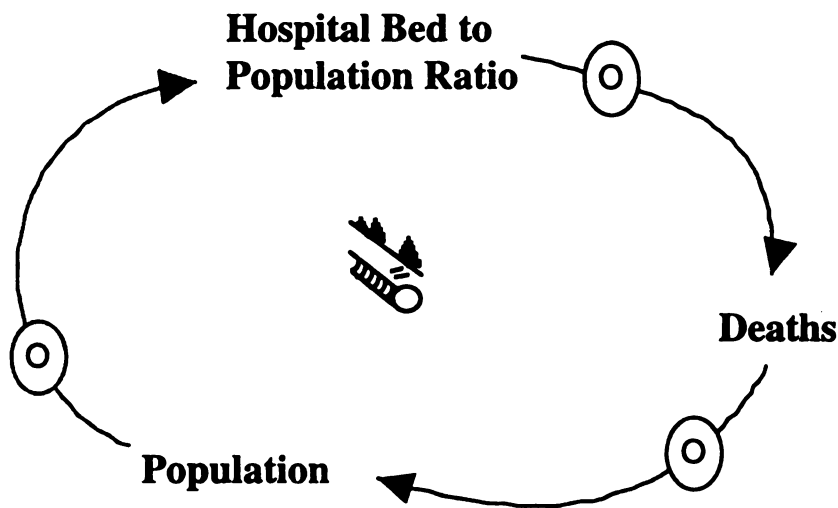


Figure 15. Health Services - Deaths - Population Loop

School Enrollment - Literacy Rate - Productivity - Income Loop

Four loops are integrated in Figure 16. Three of them are reinforcing loops, and one is a balancing loop. Intersectoral dependencies are represented through two of the

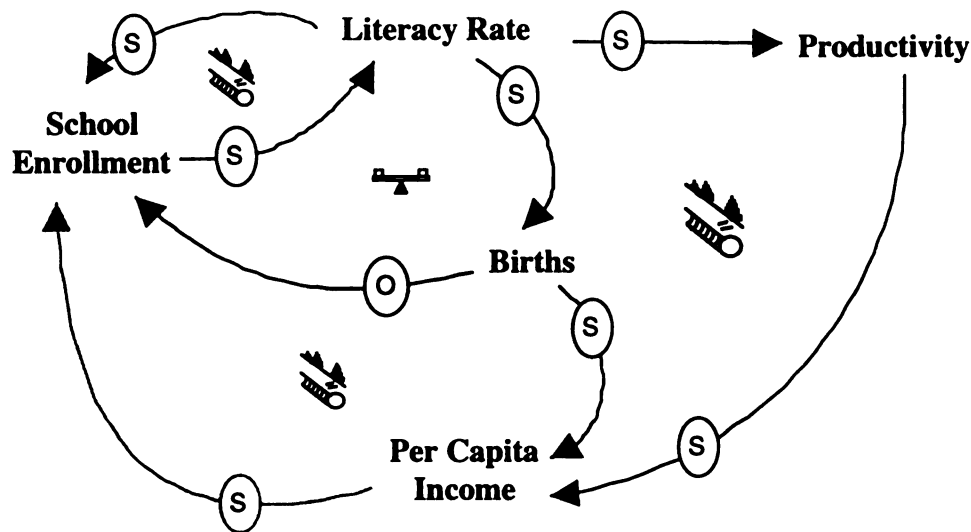


Figure 16. School Enrollment - Literacy Rate - Productivity - Income Loop

reinforcing loops and the balancing loop. As school enrollment increases, the literacy rate goes up; this tends to change society's attitude toward education and school enrollments increase. When the literacy rate goes up, productivity will increase because a better educated work force permits the increased use of new production technologies. Thus, the economic situation in terms of per capita income is improved along with educational opportunities. At the same time, the higher literacy rate will increase the acceptance of population programs and practices and decrease the birth rate. Reducing total births and population increases per capita income and school enrollment. Both

loops are reinforcing in nature. The balancing loop is the school enrollment - literacy rate - births - school enrollment loop. It is evident that the natural growth of population will increase the demand for education, while the increased literacy rate will depress the birth rate.

Pollution - Concern for Quality of Life - Concern for Economic Growth Loop

There are four causal loops included in Figure 16. Three balancing loops and one reinforcing loop. Per capita income grows in the same direction as production and visitors. As investment in tourism/recreation and investment in industrial production increase, regional per capita income will go up. However, pollution will increase as well. On the other hand, because the self-abatement ability of nature is limited by its carrying capacity, when pollution effluent increases over the carrying capacity, the self-abatement ability in nature will decay. Therefore, if more and more pollution is generated without investments in pollution control, degradation of environmental quality will become more and more serious.

In National Park areas, park management policy makers search not only for economic welfare but also environmental quality. When regional per capita income increases coupled with decreasing environmental quality, the demand for environment quality become higher. As the number of people concerned with environmental quality

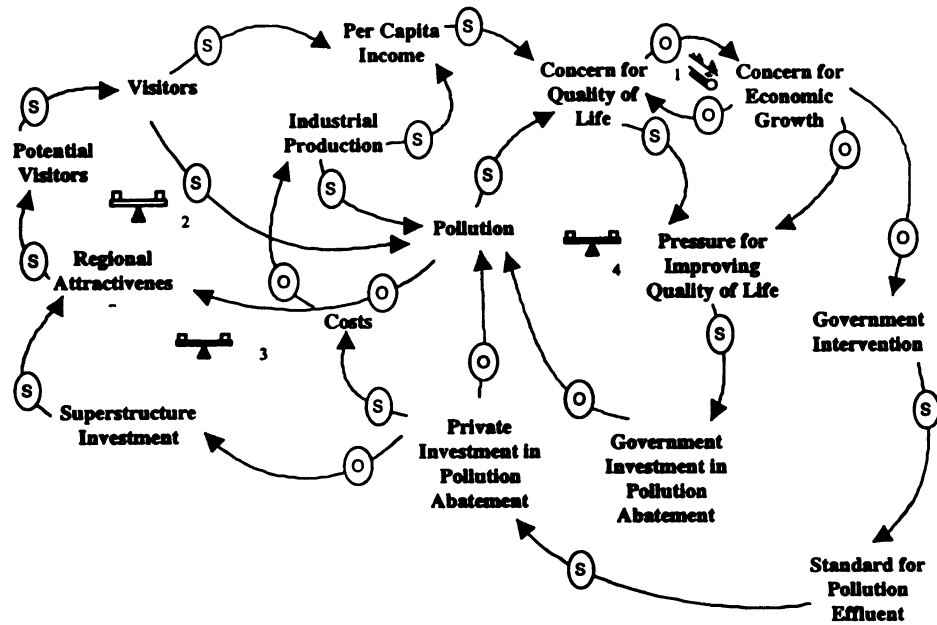


Figure 17. Pollution - Concern for QOL - Concern for Economic Growth Loop

increases, the number of people concerned with economic growth decreases. The result is that this public concern will lead to more pressure to improve environmental quality. On the other hand, pollution intervention by government will increase the pollution effluent standard and force investment in pollution abatement by private industry.

Summary of Causal Feedback Loops of the Model

Twenty-two causal feedback loops are identified in the intersectoral relationships in Figure 18. In addition, each of the sectors represented in Figure 18 consist of numerous feedback loops. The twenty-two loops include eleven reinforcing and eleven balancing causal feedback loops. Each of the loops has a separate purpose and may compete with other loops to dominate overall behavior of the National Park regional system. The development of a regional economy is generated by shifting the dominance from one loop to another. The growth phase of development is dominated by reinforcing loops. During the transition from growth to equilibrium, dominance shifts from reinforcing to balancing loops. Balancing loops determine the nature of the post-growth and equilibrium state (Forrester, 1973). In other words, the equilibrium state of an economy can take various forms depending upon which balancing loops ultimately suppress growth.

Loops	Types
1. Infrastructure Capacity - Infrastructure Congestion - Regional Accessibility - Infrastructure investment Rate - Infrastructure Capacity	Balancing
2. Load Index - Infrastructure Investment Rate - Infrastructure Capacity - Visitors - Load Index	Balancing
3. Visitors - Infrastructure Congestion - Regional Accessibility - Infrastructure Investment Rate - Infrastructure Capacity - Visitors	Reinforcing
4. Superstructure Use Rate - Superstructure Investment - Superstructure Capacity - Superstructure Use Rate	Balancing
5. Superstructure Use Rate - Superstructure Investment - Superstructure Level of Service - Regional Attraction - Visitors - Superstructure Use Rate	Reinforcing
6. Attraction - Potential Visitors - Visitors - Load Index - Attraction	Balancing
7. Resources Magnitude - Potential Manpower - Gap in Manpower - Resources Decline - Resources Magnitude	Balancing
8. Real Manpower - Gap in Manpower - Adjustment - Real Manpower	Balancing
9. Transportation Capacity - Demand/Capacity Ratio - Investment in Transportation - Transportation Capacity	Reinforcing
10. Rural Population - Rural Per Capita Income - Rural/Urban Income Difference - Rural/Urban Migration - Rural Population	Balancing
11. Population - Net Birth - Population	Reinforcing
12. Population - Labor Force - Regional Unemployment - Out-Migration - Population	Balancing
13. Wage - Regional Attraction - Capital Add Rate - Capital in Industry - Industry Production - Total Employment - Wage	Balancing
14. Health Service - Deaths - Population - Health Services	Reinforcing
15. School Enrollment - Literacy Rate - Productivity - Per Capita Income - School Enrollment	Reinforcing
16. School Enrollment - Literacy Rate - School Enrollment	Reinforcing
17. School Enrollment - Literacy Rate - Births - Per Capita Income - School Enrollment	Reinforcing
18. School Enrollment - Literacy Rate - Births - School Enrollment	Balancing
19. Concern for Quality of Life - Concern for Economics Growth - Concern for Quality of Life	Reinforcing
20. Visitor - Pollution - Regional Attraction - Potential Visitor - Visitor	Reinforcing
21. QOL - Concern for Eco-Government Intervention - Standard - Investment - Superstructure - Attraction - Visitor - Pollution - QOL	Balancing
22. Concern for Quality of Life - Pressure for Improving - Government Investment - Pollution - Concern for Quality of Life	Reinforcing

Figure 18. A Summary of Causal Effect Loops

Quantitative System Dynamics

This section discusses quantitative computer simulation modeling using dedicated modeling software. This is a more conventional and traditional phase of System Dynamics and involves deriving a system model through the shaping of relationships between all variables within the diagrams, the calibration of parameters, and the construction of simulation equations, and experiments. In this section, the calibration of parameters and the construction of simulation equations will be presented. As noted earlier, for the purpose of keeping the presentation manageable, sophisticated and complex calibration will be avoided. A computer-assisted simulation experiment and model behavior will be presented in Chapter IV.

Computer Software

As mentioned in the previous chapter, computers play a vital role in System Dynamics model implementation. It is very important to emphasize that the simulation of System Dynamics models can be carried out in any computer language. High level computer languages are most appropriate and better still is the use of purpose built software, since these encompass algorithms which facilitate the construction of dynamic models. The Powersim software was employed to execute Quantitative System Dynamics in this study. Powersim is for the IBM PC range of computers and takes full advantage of the Windows and the hard-wired graphics interface designed for these

particular computers. This software is designed so that diagrams representing models can be drawn directly on the computer screen using a predefined tool kit. The variables of the diagrams are presented by icons which can be opened to insert parameter values and relationships between variables. This program is excellent for demonstrating the relationship between system feedback structures and system behavior, and for involving system actors more closely in the model-building and analysis process. Also, this software was developed in order to provide ease of interaction for gaming simulation models and to build user interfaces for data input and output.

General Structure of Equations

In converting the causal effect loops introduced previously to a computer structural diagram, all assumptions made in the model are expressed in terms of mathematical equations or table lookup functions. Basically, the structure of the system is perceived as consisting of three basic components: levels, flows and auxiliaries. Also, the delay concept and function will be discussed in this section. A simplified structural diagram is shown in Figure 19.

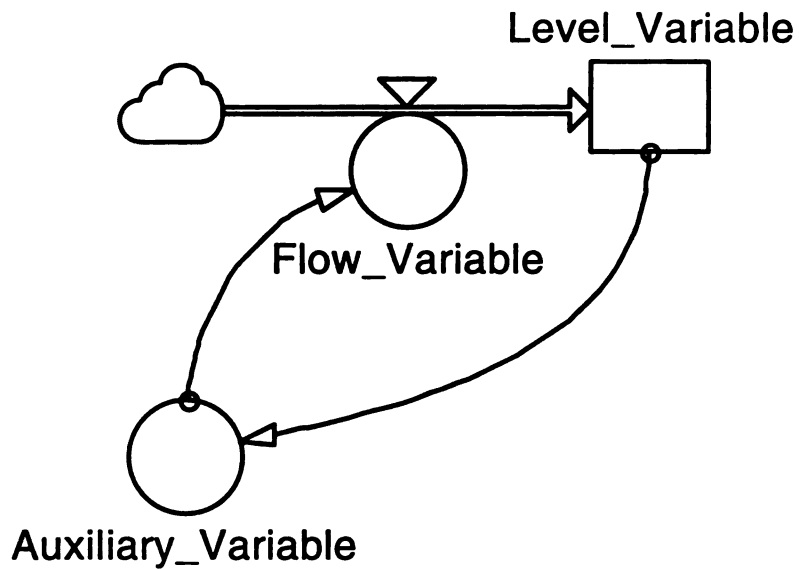


Figure 19. A Simplified Structural Diagram

Level, Flow and Auxiliary

In mathematical terms, it is noted that level equations are "integrating" equations that accumulate the net result of past rate of change in the level. If a differential equation formulation is used, these equations would appear as integrals:

$$\text{LEVEL}_{t+1} = \text{LEVEL}_{t=0} + \int_0^t (RA - RS) dt$$

That is, the level at time t+1 (for example, number of employees) is the level at t=0 plus the cumulative flow [input (RA) less output (RS), e.g., hiring (RA) less turnover (RS)] to date. The time (dt) quanta is being used. In other words, the RA-RS can be represented as a rate variable. This rate variable denotes that the net rate of change of the level variables is the inflows minus the sum of the outflows. The logic here is that level variables are calculated at the current time and the rates are projected for the forthcoming time period. Time is then moved forward in the simulation software by dt. On the other hand, level variables represent an accumulation of flows into the system such as inventories of goods, population, recreation resources, etc. Rates of flow represent the activities and decision functions in the system such as the movement of goods, migration, demolition of housing, as well as generation and depreciation of capital, etc.

When the variable is expressed in the Powersim computer program, the equation for a level variable can be displayed as follows:

$$\text{LEVEL}_{t+1} = \text{LEVEL}_{t=0} \dots\dots\dots (1)$$

$$+(dt)*(RA) \dots\dots\dots (2)$$

$$-(dt)*(RS) \dots\dots\dots (3)$$

The meaning and dimensions of these variables are provided below.

$\text{LEVEL}_{t=0}$: The initial value of level variable.

dt : The term dt denotes "delta time", which is the integration interval in the simulation.

RA : Rate being added to the level variable.

RS : Rate being subtracted from the level variable.

The first part of a level equation defines the level's initial value. In this case it can be represented as $LEVEL_{t=0}$. The second part of a level equation defines the inflows ($+dt*$...) and outflows ($-dt*$...). For each new time step (dt) in the simulation, each level variable is assigned a value which is equal to the level's previous value plus dt multiplied by the sum of the flows. In this case, the level is increased by RA and decreased by RS.

Levels and rates form the fundamental building blocks for the modeling of a system, but it is rarely feasible or desirable to specify all rates solely in terms of the levels in a system. To make the definition of the rate variables clearer and easier, a class of auxiliary variables is used.

In terms of the feedback structure of a system, auxiliary variables simply bridge the gap between levels and the rate changing other levels. In the practice of modeling, however, auxiliary variables tend to be most numerous and represent important concepts in the system under consideration. Auxiliary variables tend to be based on information within a system and act to control the physical components of the system.

Delay

One of the most important features of the systems approach to modeling is the recognition of the saliency of lags and delays in the ways systems respond to changes

within the system as well as to external simulation (Levine, 1993). Some forms of delays which are used in this study will be discussed in this sub-section. A “shorthand” notation is introduced to represent the actual level and rate equations for delay.

According to Forrester (1961), delay is a conversion process that accepts a given inflow and delivers a resulting flow rate as the output. The content of the delay increases whenever the inflow exceeds the outflow. In empirical research, not all delays in a model need to be estimated. It is often the case that System Dynamics models are completely insensitive to a delay and occasionally the case that even the time length is unimportant. Therefore, simplifying the delay used is necessary. Two kinds of simplifications are always used to reduce the number of points at which delays must be introduced into a model formulation. First, many system delays will be judged to be too short to affect the system’s behavior. Such delays are negligible compared with the other longer or more significantly located delays. Second, some delays arise from separate, processes which are cascaded one after the other and can often be combined into a single delay representation.

There are two classes of delays: material and information. The difference between these classes does not affect the numerical results unless the length of the delay is changing. Levine (1993) demonstrated that in many recreation, physical, and economic systems, delay processes entail holding, manufacturing, building, growing, and other activities which take time. A good example is that it might take 12 weeks to retrain a group of workers who have been laid off their previous jobs. Unlike the information delay, there are material things

stored in stock for that length of time. In other words, in the material delay, whatever is being delayed is considered a physical substance and is conserved as the length changes; in the information delay it is not.

When applying delay concepts in a flow channel within a mathematical model, several computational processes might be used to create a delay form. In System Dynamics modeling, exponential delays are commonly adopted in the application. There is no need to exclude other kinds of functions that could be used to create delays in a flow; however, exponential delays are simple in form, and they have adequate scope to fit modelers' usual degree of knowledge about the actual systems to be represented (Forrester, 1961).

Delays can be characterized by their "order," the number of levels through which the variable being delayed passes. The "order" of a delay is an integer greater than or equal to 1 that determines the shape of the delay. A first-order delay of a variable produces an exponential average of past values of that variable; an n th-order delay is a sequence of n first-order delays². The graph shown in Figure 20 represents the response of delays of increasing order, all having a delay time of 10. Lower-order delays have an immediate response that is dispersed. Higher-order delays have a deferred response that is more concentrated. The choice of the order of delay depends upon the modeling context, but a third-order form is commonly used to create an approximately normal

² The detail mathematical computational processes of "order" of delays can be found in Rander (1980) Elements of System Dynamics method, pp. 162-183.

distribution of output from a given input. In the Powersim computer program, the SMOOTH function may be used to represent first-order delays. To access the total quantity contained in a third-order delay, the DELAYINF (n th order information delay) and DELAYMTR (n th order material delay) are used.

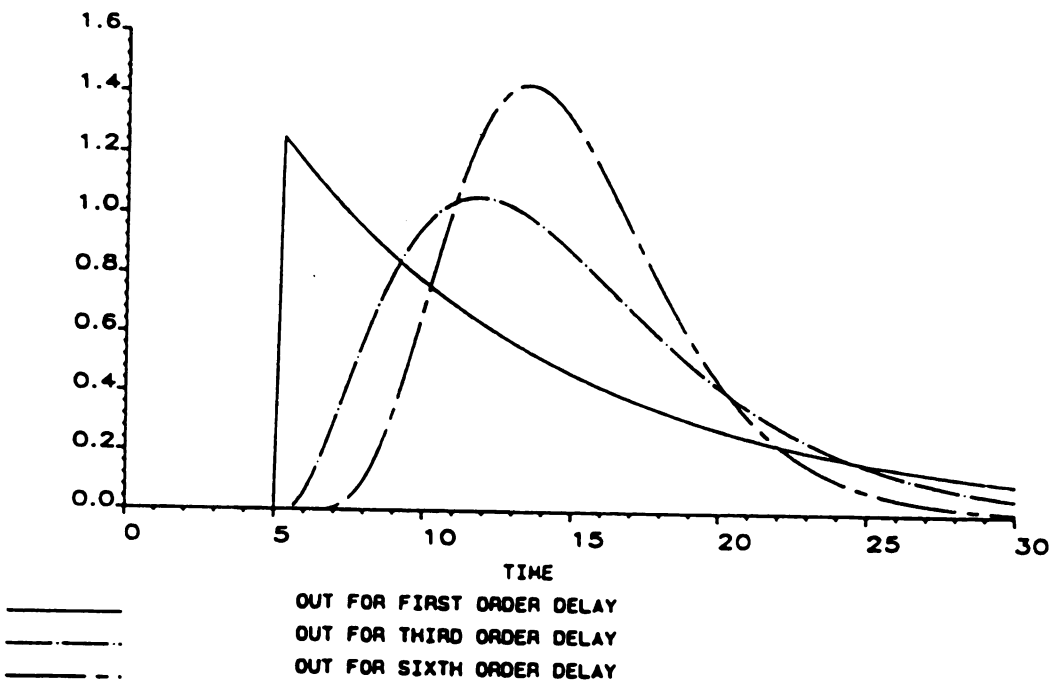


Figure 20. Output of Various Orders of Delay

Source: Wolstenholme, 1990

Table function

Although equations are one way to represent the relationship between variables, many systems contain quantities that are related to each other in ways for which algebra is not well suited. These are situations where the modeller knows how two variables are related at a causal level and can express the relationship graphically. In other words, table functions are useful when modellers do not know the exact mathematical formula of a function or when modellers want to use statistical or empirical data to express a relationship between two variables. Figure 21 represents an example of a table function for two different seasonal patterns in two National Park regions.

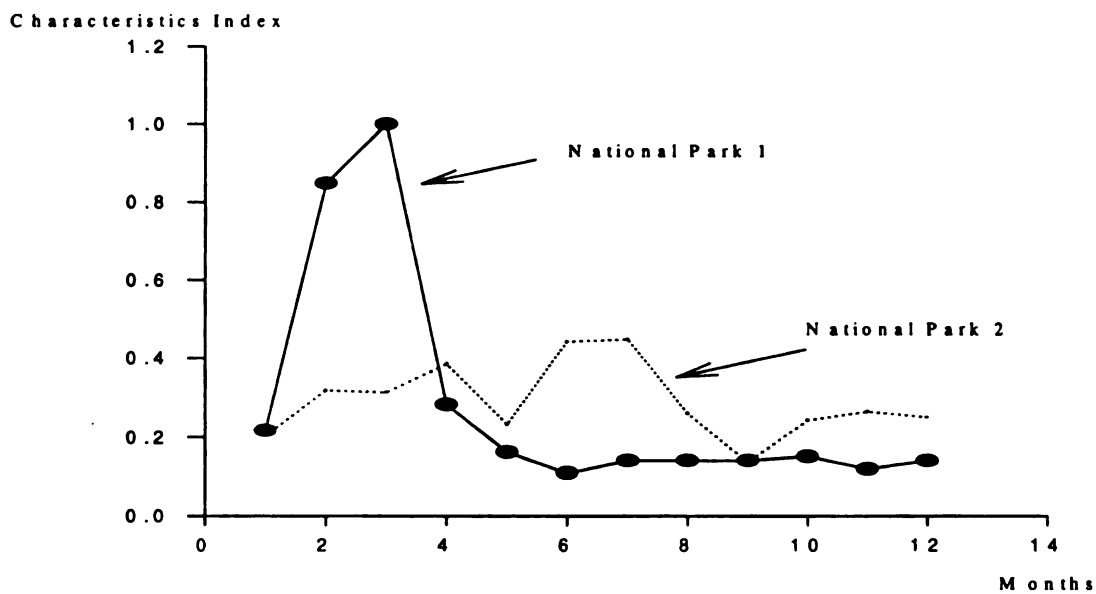


Figure 21. Example of a Table Function

Key Variables Formulation

In the previous section, the general equations for level variables and rate equations are explored. In this section, the structural diagrams for separate sectors and some selected key variables formulations which are associated with regional economic development will be discussed in detail. A full set of the equations for each model appears in the equation listings in the text and in the complete model listing in appendix B.

Tourism and Recreation Resources Sector

Recreation Resources

It is very difficult to quantify recreation resources without specifying the characteristics of a specific recreation region. For this model, it was assumed that the main resources that are considered to attract visitors include visually pleasing scenery and recreational opportunities, such as forest recreation, lake shore frontage, wilderness landscape, etc... Thus, in a park region, the magnitude of recreation resources is represented by positive contributions to the resources of the region that have been developed or managed to attract visitors. Hence, in this model, the area developed for recreational use within the particular region being modeled represents the magnitude of the recreation and tourism resources.

The structural model diagram of recreation resources is shown in Figure 22. The rate of recreation resource development is calculated as potential recreation resource

divided by the time period required for developing recreation resources, and then times the ratio of technology manpower. In other words, technology manpower is considered a controllable variable in recreation resource development. The equation can be represented as follow:

$$\text{ResDevRate} = (\text{PotDevRes} / \text{DevPeriod}) * \text{RatioTecMan}$$

where

ResDevRate: recreation resources development rate

PotDevRes: potential recreation resources (represented by acres)

DevPeriod: the time period for development of recreation resources (years)

RatioTecMan: ratio of technology manpower

The recreation resources decline rate can be calculated as, the recreation resource magnitude divided by the average time period for resources to decline, multiplied by the gap in management manpower. The gap in management manpower is only a control variable intended to maintain the management manpower needed to achieve the desired management manpower level. Without adequate management manpower, resources decline may become very small, however, it is impossible to lower the decline rate to zero. The calculation is as follow:

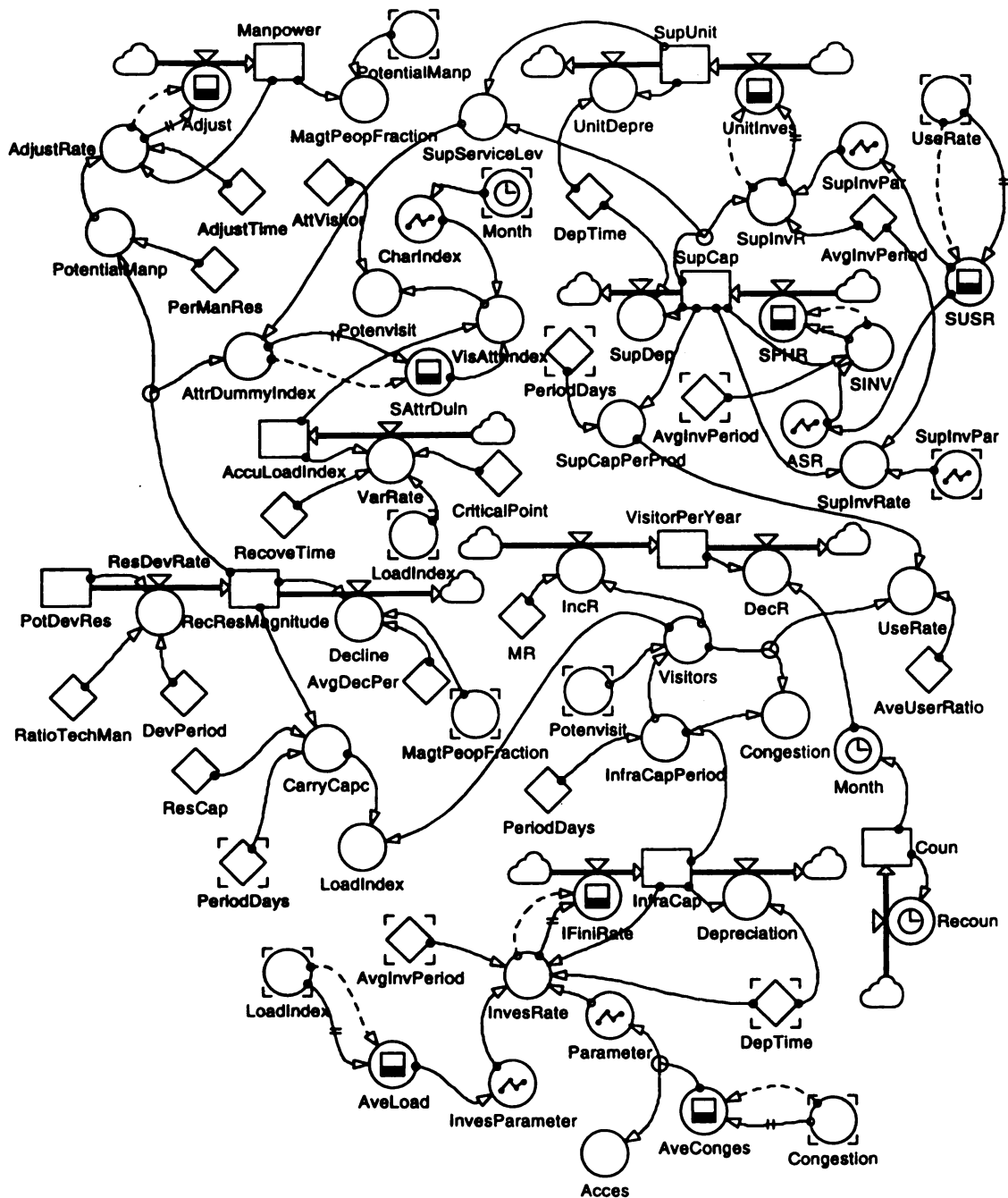


Figure 22. A Structural Diagram of the Tourism and Recreation Sector

$$\text{ResDecline} = (\text{RecResMagnitude} / \text{DevPeriod}) * \text{GapManRate}$$

where

ResDecline: rate of resources decline

RecResMagnitude: developed recreation resource magnitude

DevPeriod: average time period for resource decline

GapManRate: gap in rate of maintenance manpower

Carrying capacity and load index are two important indicators for measurement of the acceptable space for visitors. In this model, they are represented by the concept of density. The two indicators are also used to control resource decline and feedback concerning visitors' quality of experience. The carrying capacity for a recreation area is given by:

$$\text{CarryCapac} = \text{ResCap} * \text{RecResMagnitude} \quad (\text{persons/time period})$$

where:

CarryCapac: carrying capacity (persons/time period)

ResCap: space standard for one person (person/acre)

RecResMagnitude: recreation resource magnitude (acre/time period)

$$\text{LoadIndex} = \text{Potenvisit} / \text{CarryCapac}$$

where:

LoadIndex: Load Index

Potenvisit: Potential Visitors

CarryCapac: Carrying Capacity

According to the equation, if the load index is greater than 1, the carrying capacity cannot accommodate an increase in number of visitors; therefore, the attractiveness of recreation resources will decline. In the model, a dummy variable named "accumulated load index" is used for estimating the degree of decline of recreation resources. If the accumulated load index is greater than 1 in a continuous time period, then the regional attractiveness of recreation resources will decline throughout the time period. This continuous time period is called a critical period. If the load index is less than 1, recreation resources will recover gradually and the accumulated load index will decrease. The time period for recreation resources recovery is called recovery time.

Visitor Attractiveness

The function of tourism and recreation demand is reflected in the visitor attractiveness index (VisAttrIndex) and potential visitors displayed in the causal effect diagram. In the equation used to depict this in the model, the first order delay exponential average function (DELAYINF) is used to represent the delayed value of information. The delayed value of information considers the time lag between increases in recreation resources and/or level of services and the resulting increase in the number of visitors.

Recreation Area Characteristics

Recreation and tourism primarily are seasonal businesses (Mill & Morrison, 1985). Thus, visitors have a unique distribution according to each area's particular characteristics and the particular season of interest. If the area has different characteristics, it will have a different visitor distribution. The TABLE function of the relationships between visitors and season (time) is shown in Figure 23. These relationships are represented by the CharIndex variable.

Infrastructure Capacity

The construction of infrastructure has delay information value, so it will be represented by a third order delay exponential function. This means that only when decision makers sense that the over crowding has occurred, do the processes of budgeting and planning for improvements begin. Infrastructure depreciation can be calculated as follows:

$$\text{Depreciation} = \text{InfraCap} / \text{DepTime}$$

Where

Depreciation: depreciation of infrastructure
 InfraCap: infrastructure capacity
 DepTime: average depreciation time period

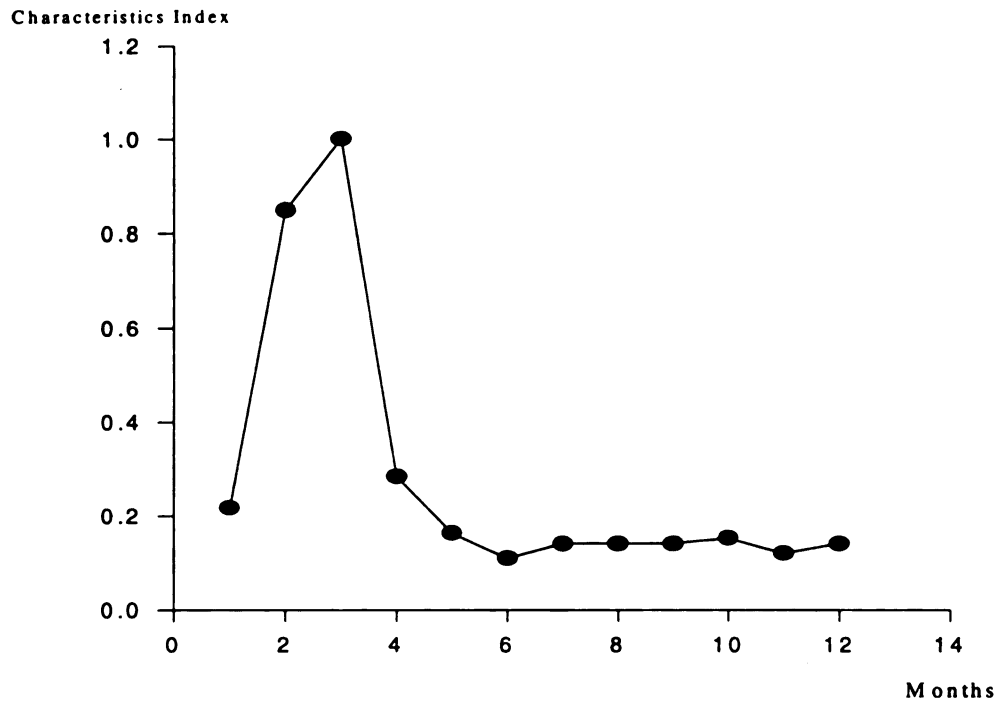


Figure 23. National Park Characteristics Index

Investment decisions are made according to the congestion level and load index value achieved. The TABLE functions of infrastructure investment criteria are shown in Figure 24 and Figure 25. The relationships among average congestion, average load index and the investment coefficient are exhibited in these two figures.

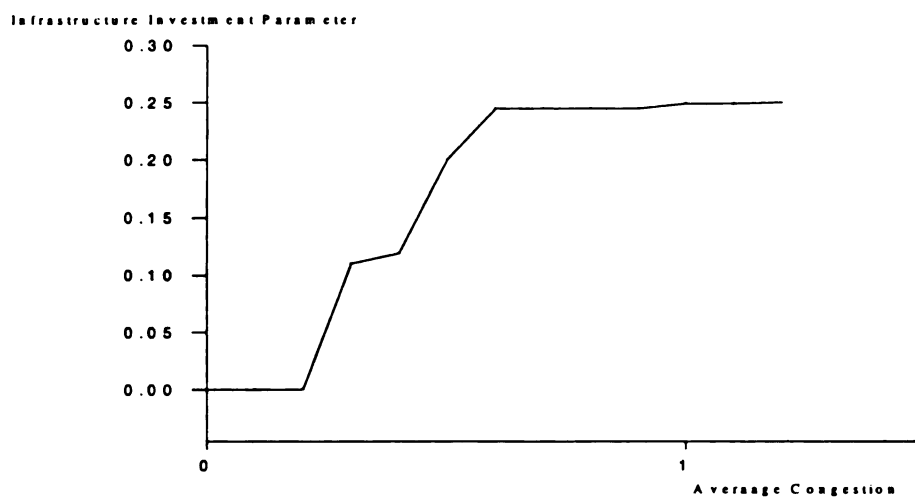


Figure 24. Infrastructure Investment Criterion Based on Congestion

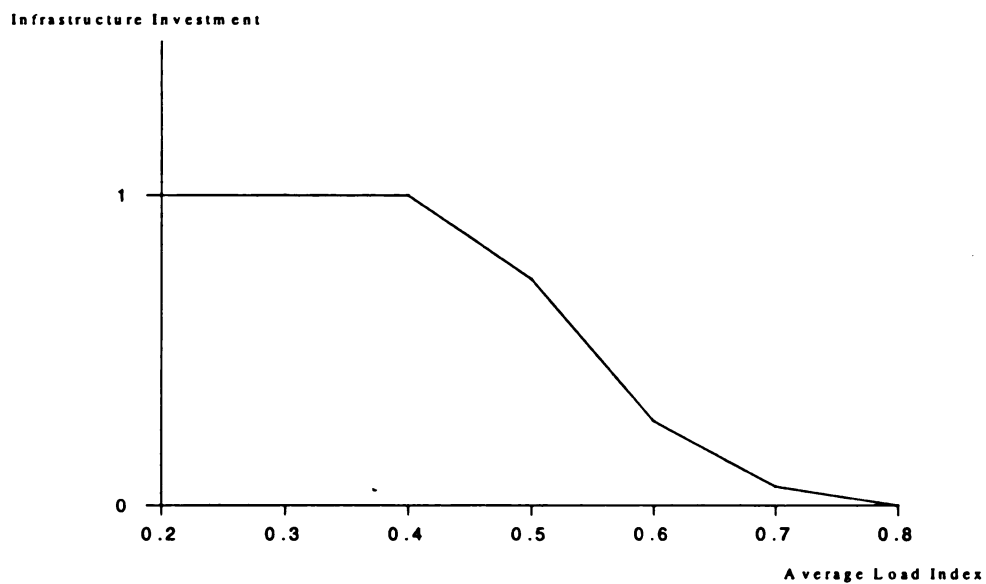


Figure 25. Infrastructure Investment Criterion Based on Load Index

Superstructure Capacity and Level of Service

For the model, it is assumed that not all visitors will use the superstructure. The proportion of visitors (represented by variable AveUserRatio) represents the ratio of visitors (less than 100%) that actually use the superstructure. The superstructure use rate can be calculated as follows:

$$\text{SUseRate} = \text{AveUserRatio} * \text{visitors} / \text{SupCapPerProd}$$

where

SUseRate: superstructure use rate

Visitors: numbers of visitors (persons/time period)

SupCapPerProd: superstructure capacity per time period (persons/time period)

AveUserRatio: average ratio of visitor use of the superstructure

Decision makers will determine investment in superstructure according to the superstructure's use rate and investment criteria. Investment criteria represent the level of investment for superstructure to accommodate a given level of superstructure use. The relationship of use rate and investment criteria is presented by a TABLE function and is shown in Figure 26.

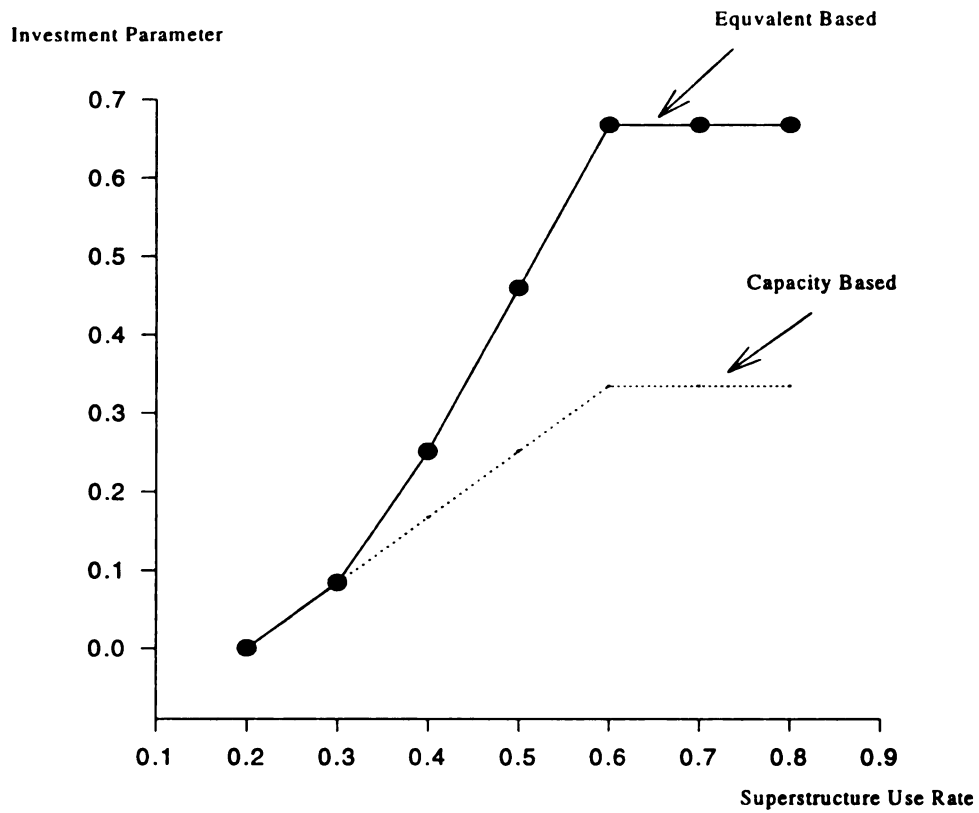


Figure 26. Superstructure Investment Based on Use Rate

Another key variable in the model is level of service (SupServiceLev). Level of service is the overall measure of all superstructure service characteristics that affect visitors. Level of service is a basic element in attracting potential visitors to the National Park regional system. For simplicity, the superstructure level of service in the model only assumes two kinds of superstructures, which are A and B. Each is weighted to represent the proportion of superstructure level of service in this area. The level of service index can be calculated:

$$\text{SupServiceLev} = (C_a * \text{SCAP}_a + C_b * \text{SCAP}_b) / \text{SCAP}_a + \text{SCAP}_b = \text{SupUnit} / \text{SupCap}$$

where

SupServiceLev: superstructure level of service index

SupUnit: Superstructure Equivalent Unit

SupCap: Total Superstructure Capacity

C_a : weight of A superstructure capacity

C_b : weight of B superstructure capacity

SCAP_a : capacity of A superstructure

SCAP_b : capacity of B superstructure

The model assumes that C_a has a value of 2, and C_b has a value of 1. The resulting level of services of superstructure A is double that of the level of services of superstructure B. The existing superstructure level of service index assumed for this area is close to 2. In other words, the level of services of superstructure A is increasing more rapidly than that of superstructure B. Similarly, if the index is close to 1, the level of

services of superstructure B is increasing gradually. In summary, the superstructure level of service index reflects the superstructure quality change for the area.

Economic sector

The economic sector can be described in two figures. In Figure 27, the employment subsector is an important indicator in guiding economic development decisions in the National Parks region. Included in this sector are employment, per capita income, and wage rate. In Figure 28, the land use subsector is presented.

Wage, Per capita income, and Employment

The relative wage rate is an important variable in Figure 27. It gives an indication of the difference between the national average wage rate and the region's average wage rate. The relative wage rate in the region is thus the ratio of the regional average wage rate to the national average wage rate. The relative wage rate depends upon the target relative wage rate and the time required to attain it. The target relative wage rate is defined as that relative wage rate which will eventually become the relative wage rate after an appropriate time lag. The target relative wage rate is a function of the average wage rate, lagged unemployment ratio and minimum wage. If the target wage rate is higher than the minimum wage rate, the target relative wage rate is determined by the average wage rate and lagged local unemployment ratio, otherwise the target relative

Figure 27. A Structural Diagram of the Employment Subsector

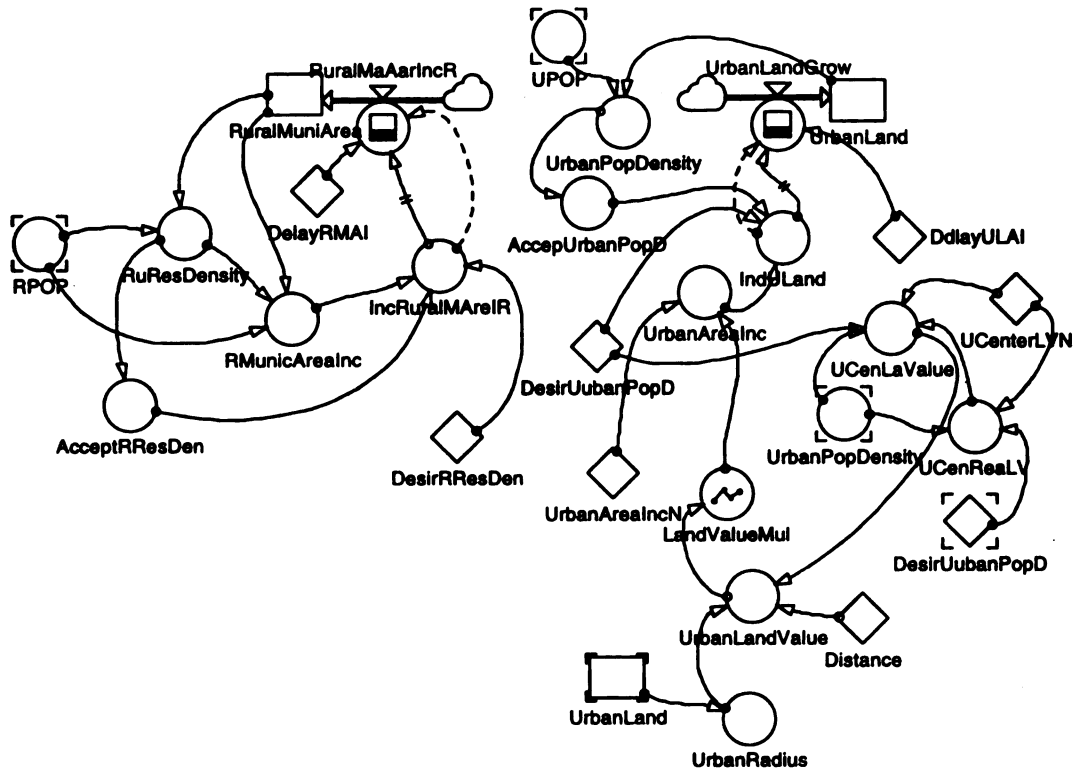


Figure 28. A Structural Diagram of the Land Use Subsector

wage rate is given by the ratio of the minimum wage rate to the national average wage rate. The national wage rate is assumed to be fixed. Average wage rate is total wages divided by total employment. The following conditional equations give the target relative wage rate.

$$\text{TargetRw} = \text{IF} (\text{TarWage} > \text{MiWage}, \text{TargetRW1}, \text{TargetRW2})$$

where

TargetRW: target relative wage rate

TarWage: target wage rate (Dollars/Persons/Day)

TargetRW1: target relative wage rate1

TargetRW2: target relative wage rate2

MiWage: minimum wage rate (Dollars/Persons/Day)

From the above, it can be seen that if the target wage rate is greater than minimum wage rate, the target relative wage rate will equal target relative wage rate1; otherwise, the target relative wage rate will equal the given target relative wage rate2.

It is assumed that only wages comprise income. Property income is assumed to be negligible. In fact, wages in many cases represent disposable income. Hence, it is assumed that the indicator of regional economic development is per capita income arrived at by using total wages and that per capita income affects other economic variables. Per capita income is total wages divided by total population. Rural per capita income is wages that accrue to the rural population divided by the number of rural residents in the

region. Urban per capita income is sum of business and service wages divided by the number of persons living in the urban region.

Land use

The land use sub-sector in the economic sector is shown in Figure 28. It is concerned with human activity in a very broad sense. It is concerned with the living patterns of households, productive patterns of industries, selling patterns of retail and personal service establishments, and the many other classes of activity patterns that exist and interact as elements in the regional social system. Thus, from this viewpoint, "land use" means a great deal more than existing or proposed improvements visible on the ground. Another very important element of the land use subsector is that it is intended to capture a constantly evolving and continuously changing phenomenon. Thus, the model is designed to mimic the dynamics of expansion of land areas in the region.

Urban land areas and rural residential lands are represented by level variables and which are increased by expansion rates. The land area increase rate both in urban and rural areas is a first order delayed function of the indicated increase rate. It is much easier to obtain land in the rural area; therefore, a longer delay time for urban land expansion is assumed. Because the acceptable population density indicates the point at which expansion of urban areas and rural residential land starts, as population density approaches acceptable limits, the impact of crowding and higher density and pressure to

expand becomes more severe and urgent. It is assumed that the rural acceptable population density is 1.2 times the actual population density and that the urban acceptable density is 1.5 times the actual density. Next, the value of the indicated expansion rate is to be determined. It is assumed that required land for expansion in rural area is the difference between the desired land area and the acceptable land area. This relation is expressed as follow:

$$\text{RMunicAreaInc} = \text{RPOP} / \text{RuResDensity} - \text{RuralMuniArea} / 1.2$$

where:

RMunicAreaInc: required land for expansion in rural area (Hectares)

RPOP: rural population (Thousand Persons)

RuResDensity: desired rural residential area population density (Thousand Persons/Hectare)

RuralMuniArea: rural residential land area (Hectares)

Before considering the urban expansion rate, it must be noted that it was assumed that the land needed for urban expansion is always available during the simulation period. Thus, the indicated urban expansion rate depends not only upon the population density but also upon average land value. The model assumes that the average urban land value is the principal factor affecting the quantity of land available for expansion. A multiplier is used to specify this effect. The assumed relationships between urban population density and, land area expansion, and land value is included in the model as a TABLE function which is shown in Figure 29.

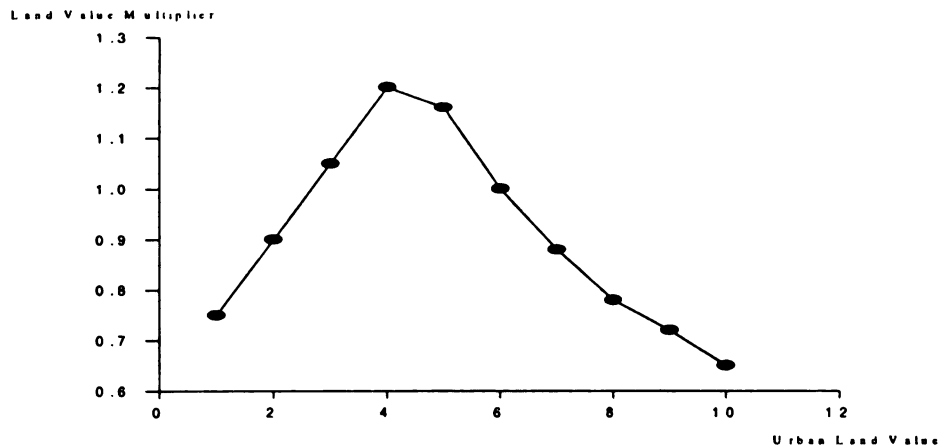


Figure 29. Land Value Increase Multiplier for Urban Land

It is evident that initially land value increase has a positive influence on urban land, but, after a certain level of land value is reached, the trend is reversed. The average urban land value follows Mills' land rent theory (Owen, 1964) that:

$$R(U) = R_0 e^{-AU}$$

where

$R(U)$: land rent at distance (U) from city center

R_0 : a constant of integration interpreted as land rent at the city center

e : natural base of logarithms

A : exponent specifying the land rent change which depends upon the size, pattern, and function of the city

U : distance from city center

Applying Mills' theory, the model assumes that the land value in the urban center changes when the urban population density is greater than the desired population density and there is an increase in proportion to the ratio of actual to the desired population density. The actual population density is simply the ratio of current population to current urban land acreage.

The Environmental Sector

The structural diagram of the environmental sector is displayed in Figure 30. The environmental sector plays a trade-off role between economic growth and environmental pollution. Pollution is a level variable. It is in essence a pool in which pollution discharge accumulates and from which pollution then empties. The pollution index is an indicator to represent the trend in pollution accumulation. The index is based on the ratio of the pollution pool (Pollution) to pollution standards (PollInStandard). Also, concern for economic growth and concern for quality of life are two indicators which represent the trade-off relationships involved in the environmental sector of the model. The latter relationship is defined in a TABLE function which is displayed in Figure 31.

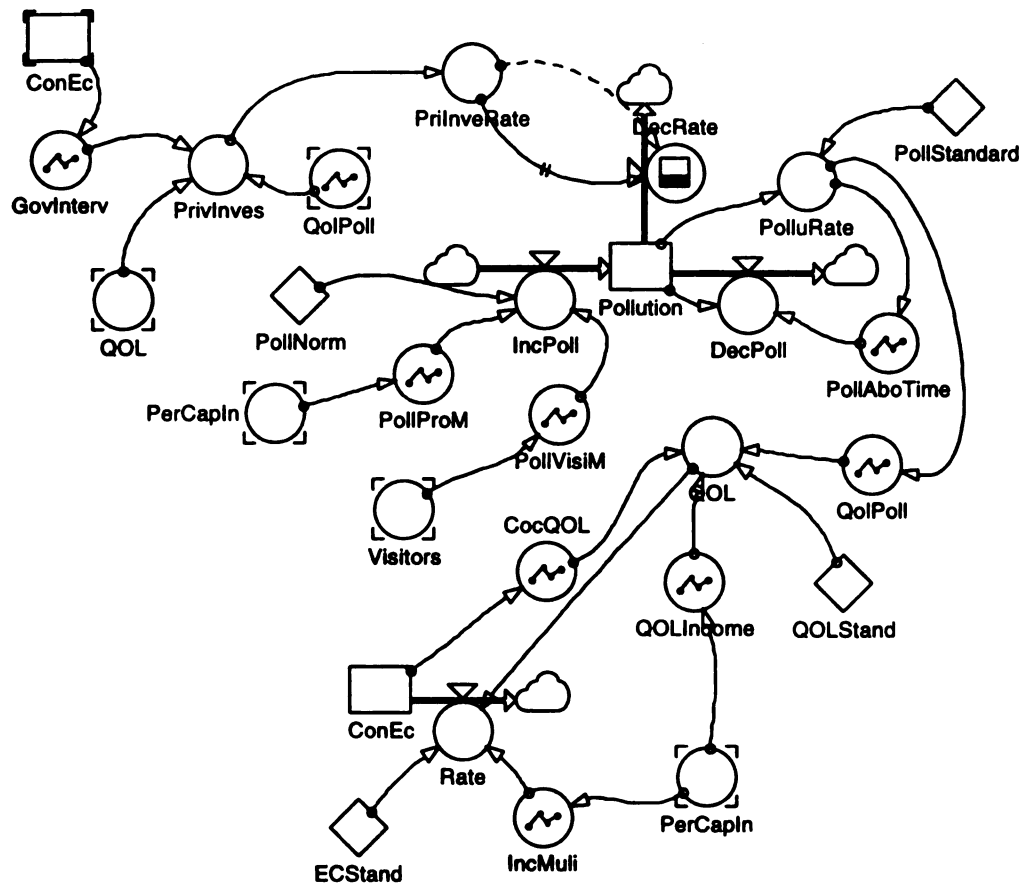


Figure 30. A Structural Diagram of the Environmental Sector

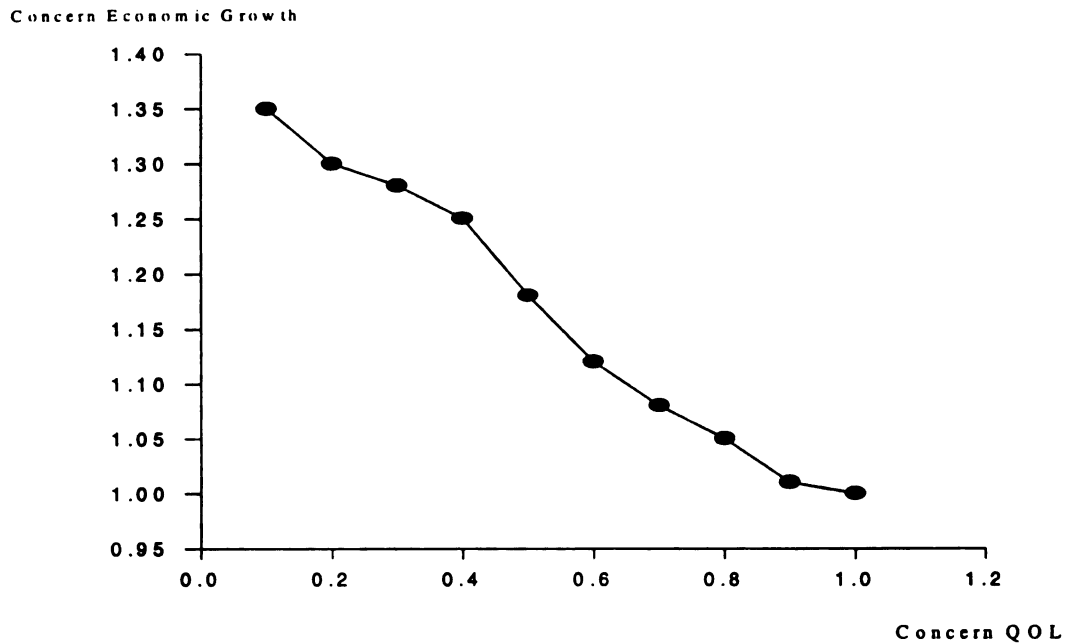


Figure 31. Concern for Quality of Life vs. Concern for Economic Growth

Population Sector

The population sector is shown in Figure 32. Development of the population sector basically follows the cohort-survival method. Here, the components of the method are birth rate, death rate, and aging rate. The birth rate is calculated by dividing the number of live births in a year by population in the same year. Similarly, the death rate

Figure 32. A Structural Diagram of the Population Sector

is calculated by dividing the number of deaths in a year by population in the same year. Aging rate to the next cohort is a reciprocal number of the number of people within each age group. It is assumed that the number of people of each age within an age group is the same. For instance, the number of individuals 13 years old within the 12-17 year old age group is assumed to be 1/6 of the total 12-17 year olds.

The cohort-survival technique starts with age cohorts at the base year. By adding births and subtracting deaths and then aging the residual to the beginning of the next age group during the simulation period, yields the population in the next year by age and age groups. Births, deaths, and aging are calculated applying assumed age-specific fertility, survival, and aging rates to the population. These rates are determined exogenously. The model is recursive; i.e. population of one age group in a given year is a function of population of the same age group in the previous year and the appropriate fertility, survival, and aging rates. It is noted that the model cannot take into account unpredictable social and economic changes such as war and recession, which would cause significant deviations from the recent past trends in births, deaths, and migration.

The Social Overhead Sector

Three main components are included in the social overhead sector. These are: health services, population programs and practices, and education. The related structural

diagrams are shown in Figure 33 (health service and family subsectors) and Figure 34 (education subsector).

Health Services

Health services in the region are expressed in terms of hospital beds. Two level variables are used to represent hospital beds in both urban and rural areas. In both cases the level of hospital beds is increased by a rate derived from the actual-indicated-possible-desired mechanism. The desired hospital bed increase rate is proportional to the products of the medical personnel deficiency multiplier times the difference between desired hospital beds and actual beds. The relationship can be shown as follow:

$$\text{UrbanHospBedDesir} = ((\text{DUHBPR} * \text{UPOP} - \text{UHB}) / \text{UHDRT}) * \text{MPDM}$$

where

UrbanHospBedDesir: desired urban hospital bed increase rate (Bed/Year)
 DUHBPR: desired urban hospital bed population ratio (Bed/Thousand Persons)
 UPOP: urban population (Thousand Persons)
 UHB: urban hospital beds (Bed)
 UHDRT: urban hospital development realization time (Year)
 MPDM: medical personnel deficiency multiplier

Figure 33. A Structural Diagram of the Health Services and Population Programs Subsector

Figure 34. A Structural Diagram of the Education Subsector

The expansion of hospital beds has to take into account the availability of medical personnel. The TABLE function (Figure 35) shows the relationship between hospital bed increases and the medical personnel deficiency ratio.

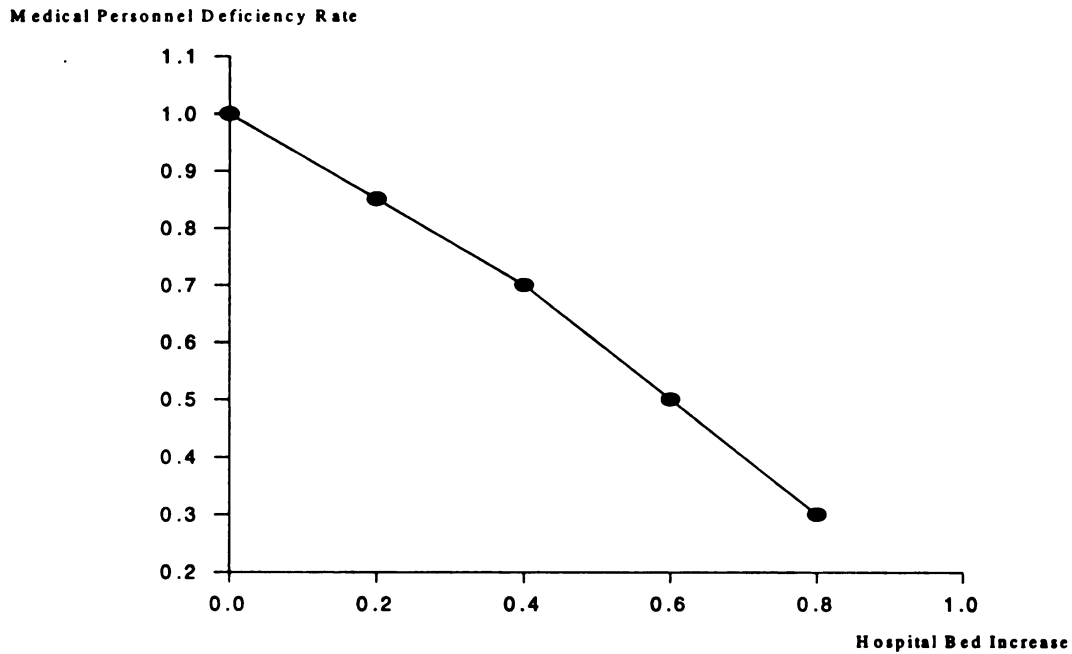


Figure 35. Hospital Bed Increase vs. Medical Personnel Deficiency Ratio

The possible hospital bed increase rate is equal to the health development budget allocation divided by the cost per hospital bed. The actual hospital bed increase rate is

the delayed value of the indicated rate which is the smaller of the desired and possible increase rates.

The demand for medical personnel is the product of medical personnel to hospital bed ratio times the number of hospital beds. Based on the report of Popoy (1971), a medical personnel to hospital ratio of 3 persons per bed is applied to this model. The medical personnel available in the region is increased by medical graduates or vocationally trained personnel, and decreased by retirement rate. Medical personnel includes all levels of vocationally and professionally trained employees in hospitals. These include doctors, nurses, technicians, and pharmacists.

Programs and Practices Affecting Population

It is rather difficult to quantitatively formulate programs, policies, and practices that affect population into the regional development model. However, based on the assumption that population program personnel are the principal force carrying out the population-related programming and practices, the model simulates the demand for such population program personnel. The influences of a population practices in the recurring natural birth rate are considered in the demographic sector of the model and will not be discussed here.

Population program personnel, referred to as population programs and practices personnel (FPP) in the model, include obstetrician, physicians, and professional family planning personnel.

It is obvious that the success of a population control programs depend principally upon the achievements of these population program personnel. The level of population personnel is increased by a training or recruiting rate and decreased by a retirement rate. It is assumed that five population program personnel per 10,000 population are needed to ensure the success of the whole program. The actual-indicated-possible-desired mechanism is applied to determine the population personnel (FPP) recruiting rate. The ratio of population personnel to regional population indicates the degree of influence on the regional birth rate.

Education

Education is the basis of manpower development. The level of education achieved by the population to a large extent determines the potential success of economic development programs. The model classifies the educational system in the National Parks region as primary, secondary, and tertiary. Pre-primary and graduate education are excluded from the model structure for the reason that they are less important to manpower development. Intermediate education is included in the primary level as is

customary in the U.S. Vocational, college, and university education are aggregated in the tertiary level.

Capital Allocation

The structural diagram of the capital allocation component of the model is exhibited in Figure 36. The principal indicator is the capital pool. The capital pool is treated as a level wherein all external loans, external aid, internal loan repayments and

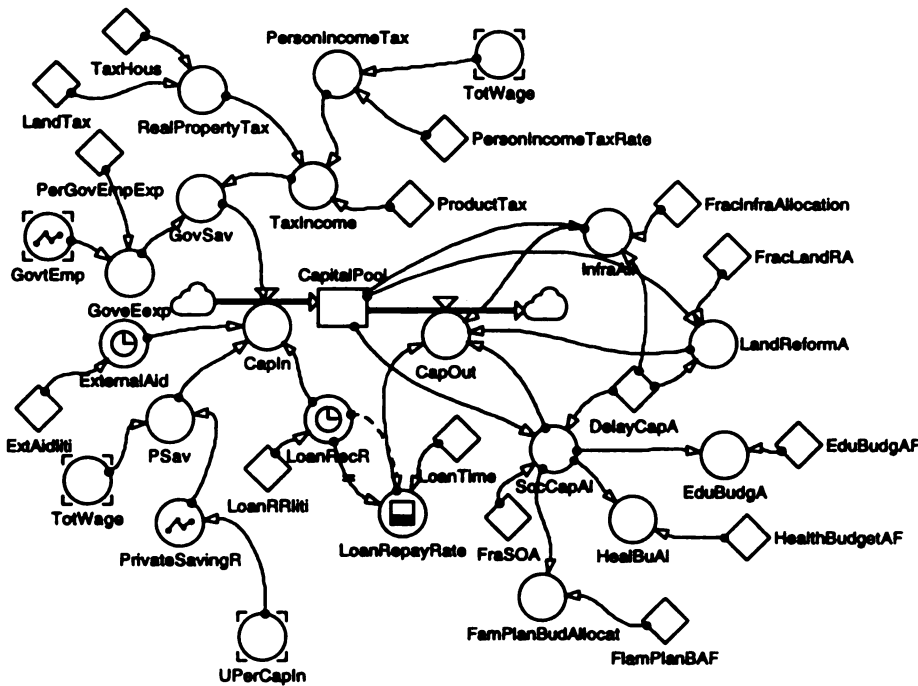


Figure 36. A Structural Diagram of the Capital Allocation Sector

savings are accumulated. Allocations are made out of this pool for various activities during each time period iteration of the model.

CHAPTER IV

SYSTEM MODEL AS AN EDUCATIONAL TOOL

Introduction

This chapter is divided into three main sections: [1] Gaming Simulation Application; [2] Case Study of the tourism and recreation sector model implemented in a classroom setting; and [3] Academic Programs, including teaching procedures and curricula planning. This chapter explains how gaming simulation can be incorporated into the learning process and illustrates the classroom uses of the National Parks regional model by providing a case study of a simulation experimental problem with accompanying suggested academic programming strategies.

Gaming Simulation Application

In an educational context, a simulation model is a powerful tool for teaching aspects of the world by limiting or replicating it. Students are not only motivated by simulations, but they also learn by interacting with simulations in a manner that approximates real situations. A simulation model simplifies reality by omitting or changing details. In this simplified world, the student solves problems, learns procedures, understands the characteristics of phenomena and how to control them, and recognizes alternative actions for different situations.

The teaching style that utilizes gaming simulation has four phases: presenting the student with information; guiding the student in acquiring information and skills; providing practice to enhance retention and fluency; and assessing learning.

Gaming screens play a dynamic role by connecting complex models with game-players who may be unfamiliar with the inner operations of models. Through gaming screens, game-players receive information on the major variables in the National Park regional system. The information received by game-players, which is enhanced and presented by appropriate game screens and interfaces, is an important basis for making policies or changing policies in response to particular regional development problems and circumstances. Each game-player can actualize his policy changes by clicking on appropriate policy buttons and by changing the position of policy levers that appear on the gaming screens.

Gaming screens provide direct interaction with the National Park regional model. They display, graphically or numerically, the changing trends of major variables in the National Park regional model. Gaming screens also convert the policy changes made by game-players into numerical changes within the regional model.

The gaming screen consists of five separate screens: [1] Policy Option; [2] Time Table; [3] Time Graphic; [4] Equation; and [5] Main Model. Convenient access to each screen is facilitated by clicking a small icon. The Main Model gaming screen is exhibited in Figure 37. The policy option screen, shown in Figure 38, contains a set of parameters.

In this policy change mode, the learner can use the pointer tool to adjust parameters of the model by moving the buttons that represent policy objective parameters.

Activating the Time Table icon on the main screen brings the user to the output screen containing scrollable fields that accumulate numerical data representing major variables. The Time Table screen is shown in Figure 39. A double click on the Time Graphic icon on the main screen reveals graphic time-series phase plots based on the numerical data. The Time Graphic screen is displayed in Figure 40. Target variables for observation can be accessed through the variables selection screens by double clicking on the screens of Figure 39 or Figure 40.

The Main Model screen is composed of the structural diagrams for each sector that is described in Chapter III. This screen helps users understand the inner relationships and workings of the model, and it helps with sensitivity analyses of the variables. A double click on the Equation icon reveals the mathematical presentations and variable definitions for the whole model.

Instruction and learning are enhanced by utilizing the gaming simulation in the classroom. The gaming simulation application allows groups of students to use the model to create and interact with various policy and management scenarios that can serve as a

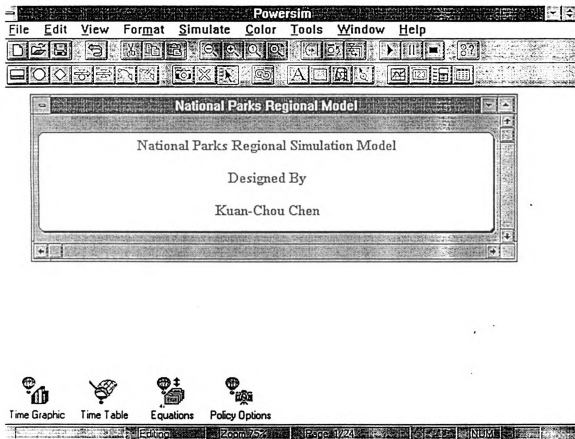


Figure 37. The Main Screen of The Gaming Simulation Model

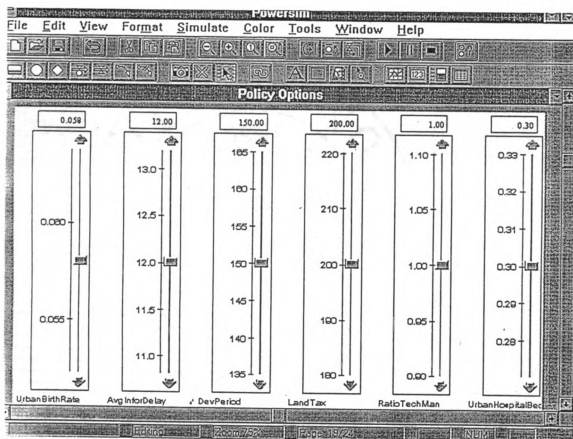


Figure 38. The Policy Options Screen

Figure 39. The Time Table Screen

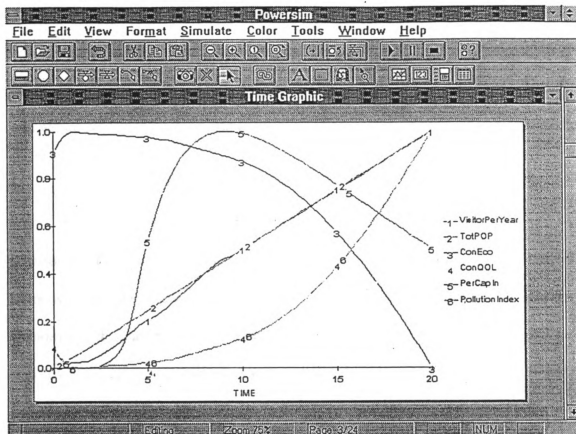


Figure 40. The Time Graphic Screen

basis for discussions and further studies. This type of interaction provides an experimental learning experience for students that is different from a traditional lecture. A case study demonstrating the use of the interactive gaming simulation model as an educational tool is presented below. Further information regarding the integration of modeling concepts and the gaming simulation interface in various academic programs and within course curricula is also discussed below.

Case Study of Tourism and Recreation Sector

To illustrate how the National Park regional planning model can perform in a classroom setting, various scenarios focusing on one of the sectors of the model will be demonstrated. This case study, of the Tourism and Recreation sector, will effectively demonstrate the gaming simulation interface, student interaction and experimentation, and how dynamic system behavior can be understood through the use of the model (for any National Park regional planning sector). The following scenarios are derived from three alternative policy development options that provide the instructor with a framework to present the material in model form to students.

Model Base Run of the Tourism and Recreation Sector

The gaming simulation interface was developed to enable users easy access and better understanding of the National Park regional model. For example, the Policy Options screen in Figure 38 requires the user to slide the bar to different options to observe its effect. Prior to implementing the model, a model base run is necessary to establish a point of reference (baseline) to accommodate policy comparison. The model base run does not require any interactive policy involvement or input. The data in Figure 41 show the simulation results of the base run of the Tourism and Recreation sector. The number of visitors increased during the first 7 years and then drops dramatically, primarily because of the discrepancy in the development of recreation resources after 7 years and the decreasing growth of superstructure capacity.

In Figure 41, infrastructure capacity growth rate rises steeply during the first 9 years. However, after the 9th year, the growth rate begins to decline. The superstructure capacity increases during the first 3 years, but steadily drops until the year 10. In Figure 42, a typical S-shape curve growth trend can be observed. According to Bronson, et al (1988), the S-shape curve is a valid representation of the fundamental relationship between variables in macrosociological theory. The value representing superstructure level of service exhibits sustainable growth during the first 8 years but declines during years 9 and 10.

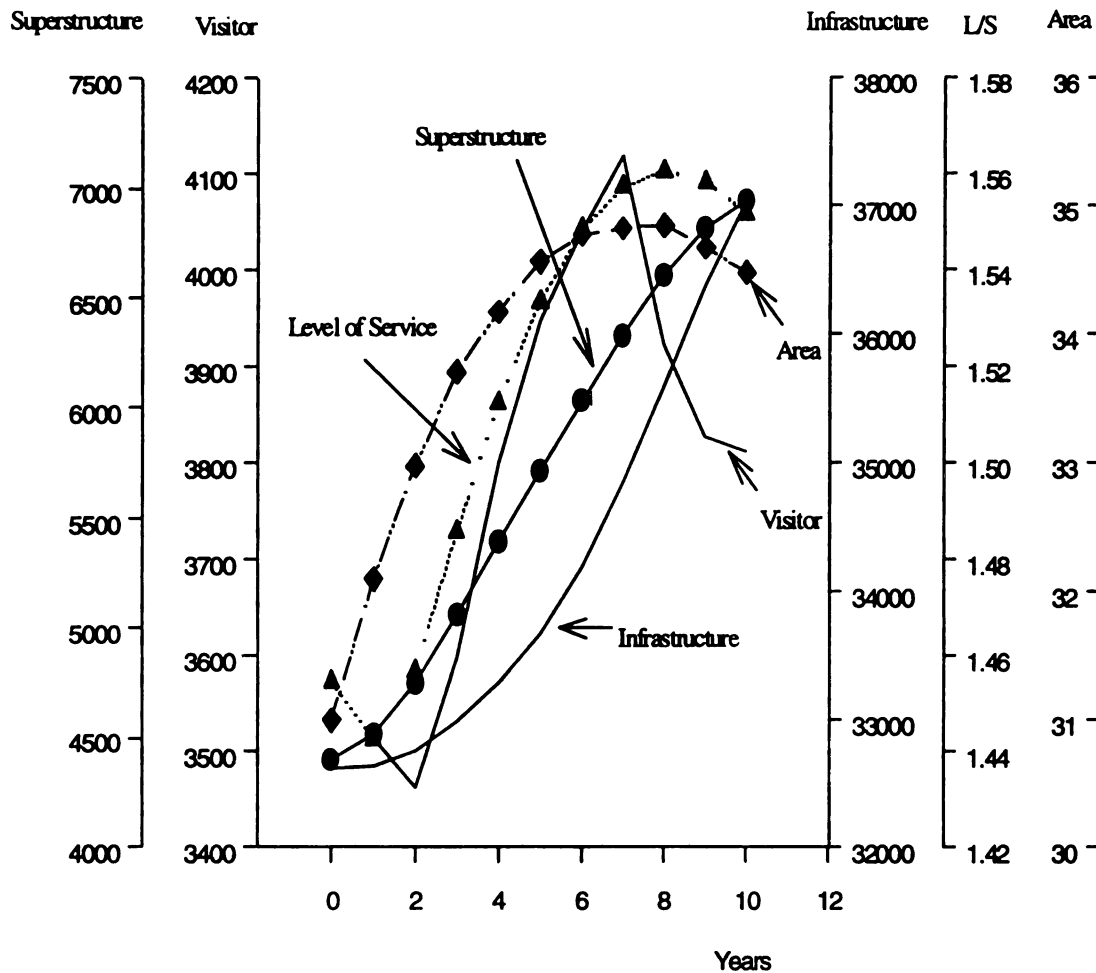


Figure 41. Base Run of the Tourism and Recreation Sector

The development of recreation resources is concentrated within the first 8 years.

The development rate is greater than the decline rate over this time period. Beyond year

8, the development rate is less than the decline rate, so developed area is decreasing after year 8.

Change in Tourism and Recreation Policy Variables

The following scenarios are derived from three alternative development policies: Tourism/Recreation Resources Development; Infrastructure Investment; and Superstructure Investment. Each of these scenarios are examined through the dynamic behavior of the National Parks regional model. The adoption of each policy is represented in the model by particular changes in the controllable parameters of the structure, i.e. changing variables through the Policy Option gaming screen. The discussions are limited to the examination of the probable consequences of adopting that particular policy and investigating the issues, if any, which might arise from taking a particular course of action. Each policy can be treated independently using the model.

Policy for Tourism and Recreation Resources Development

The scenarios used to test this particular Tourism and Recreation Development policy involve examining the effect of the policy on the number of visitors, infrastructure capacity, superstructure capacity, and level of services.

Scenario 1

Assumption: The resources development rate is equal to the resources decline rate. In this case, the resources development strategy is intended to maintain the tourism/recreation resources at a constant level.

In the base run, the model uses the following resources development rate and resources decline rate:

$$\text{ResDevRate} = (\text{PotDevRes} / \text{DevPeriod}) * \text{RatioTechMan}$$

$$\text{ResDecline} = (\text{RecResMagnitude} / \text{AveDecPer}) * (1.2 - \text{MagtPeopFraction})$$

In order to modify the model to simulate the desired scenario, the resources development rate must equal the resources decline rate. That is, the model must reflect a situation where the development of natural resources related to tourism and recreation is equal to the loss of tourism and recreation resources. To accomplish this, the above equations are replaced by the equations shown below:

$$\text{ResDevRate} = \text{ResDecline} = (\text{RecResMagnitude} / \text{AveDecPer}) * (1.2 - \text{MagtPeopFraction})$$

where

ResDevRate: potential rate of tourism and recreation development

ResDecline: tourism and recreation extraction rate

RecResMagnitude: base magnitude of tourism and recreation resources

AveDecPer: average resources development rate

MagtPeopFraction: the proportion of management manpower to total manpower

Scenario 2

Assumption: The resources development rate is less than the resources decline rate. In this case, the tourism and recreation resources are experiencing a declining trend.

In the base run, the model uses the following ratio of technology manpower:

$$\text{RatioTechMan} = 1.0$$

Since alternative scenarios are based upon the assumption that the resources development rate is less than the resources decline rate, the base model's fraction of the technology manpower input, which directly affects new resource development, must be altered. Thus, the above equation is replaced by the equation shown below:

$$\text{RatioTechMan} = 0.2$$

where

RatioTechMan: the fraction of technology manpower

Scenario 3

Assumption: The resources development rate is greater than the resources decline rate. In this case, the tourism and recreation resources variable is experiencing a positive growth trend.

In the base run, the model uses the following resources development time:

$$\text{DevPeriod} = 150 \text{ (days)}$$

When the resources development rate is greater than the resources decline rate, the value of the resources development time period in the base run, which directly affects the resources decline rate, is decreased. Thus, the equations are replaced by the equation shown below:

$$\text{DevPeriod} = 60 \text{ (days)}$$

where

DevPeriod: the resources development time period.

Results of Simulation Scenarios for Tourism and Recreation Resources Development

To facilitate comparisons among the three alternative scenarios, the number of visitors is plotted in Figure 42. Under scenario 1, the number of visitors declines steadily but at a slow rate because the development rate lags behind the resources decline rate. Furthermore, this decreasing trend becomes more severe in scenario 2 due to the lower ratio of technology manpower input. Under scenario 3, due to the higher resources development rate, the number of visitors trend reverses to a steady growth trend.

From these three scenarios, it can be concluded that resources development policy is a very sensitive factor in National Park regional development. Shortening the development time period and inputting more technology manpower into the system, therefore, are two strategies for accelerating resource development. Relationships such as these can help students understand the importance of potential tourism/recreation resources in the planning process.

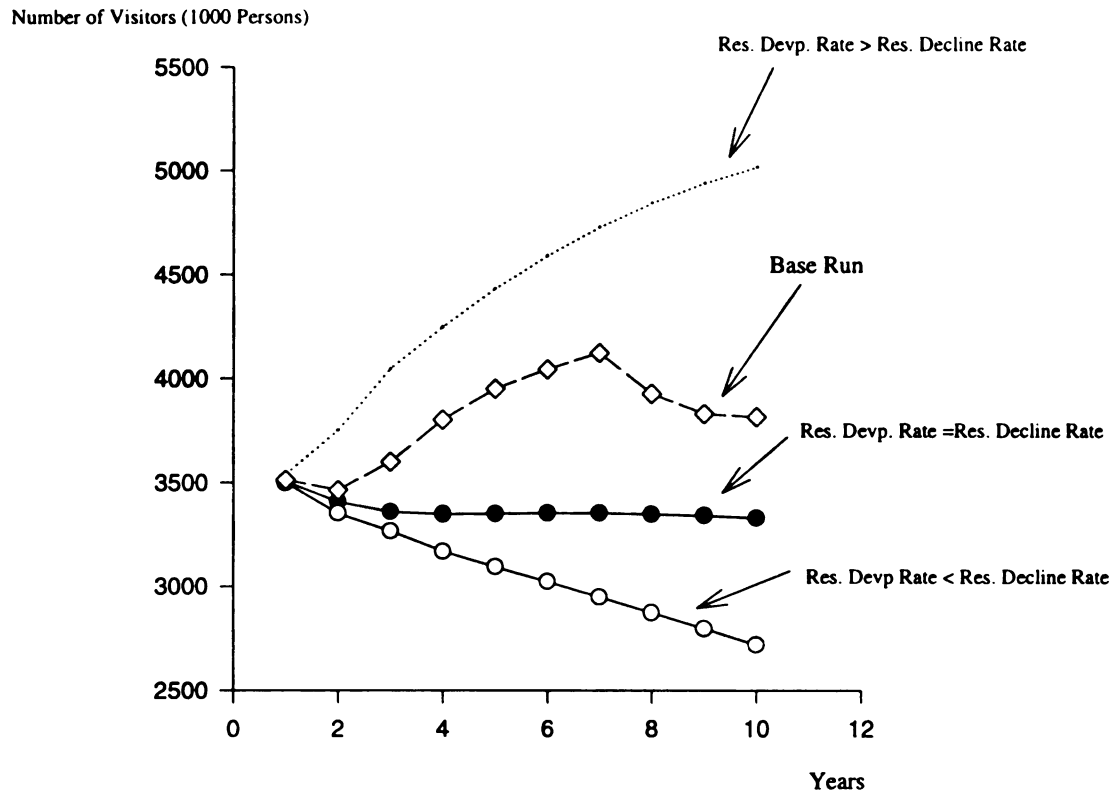


Figure 42. Comparison of Number of Visitors in Three Scenarios

Policy for Infrastructure Investment

Investment in infrastructure is a critical factor in the development process of regions. As an educational tool, the simulation experimentation can help students understand the degree of sensitivity of information delay and investment criteria among infrastructure investment alternatives. As discussed in Chapter III, experimentation with information delay can provide basic information for making efficient policy decisions. Testing investment criteria in the context of the model can provide the information needed for students to observe tourism/recreation development trends.

Test of Information Delay

The parameter change for testing the role of information delay in the National Park system is shown in Table 2. Students are shown that decreasing the information delay results in a large growth of infrastructure capacity; however, the natural resources themselves suffer from over use. Chronic over use eventually causes the number of visitors growth to become less than that of the model base run.

Table 2. Parameters for Testing of Information Delays

Testing Items	Average Information Delays
Base Run	12 Months
Scenario - Decrease Information Delay	6 Months

In conclusion, lessening the information delay promotes the construction of new infrastructure. This increase in infrastructure capacity contributes to an increase in the number of visitors. The increases in the number of visitors leads to over use of resources, which then becomes a barrier to the further development of tourism and recreation resources.

Test of Investment Criteria

The original investment criteria and two new investment criteria are shown in Table 3. The data in Table 3 shows that the proportion of infrastructure investment based upon an average crowding index ranging from 0 to 1. The assumption in scenario 1 involves conservative investment of development resources, where resources for development are applied and increased in relatively small and gradual increments. The assumption in scenario 2 involves aggressive investment of development resources,

where resources for development are applied in relatively large increments. The simulation scenario results are displayed in Figure 43 and Figure 44. These results show that the infrastructure capacity is high in scenario 2 and low in scenario 1. However, the number of visitors under scenario 2 is always lower than under scenario 1.

The data in Figure 44 demonstrate the negative effects of over investment in infrastructure. A comparison of the model base run and scenario 1 in the first simulation

Table 3. The Infrastructure Investment Criteria

Testing Items	If Average Crowding Index (0 - 1)				
	0.2	0.3	0.4	0.5	0.6
(Investment Parameter)					
Base Run	0	0	0.08333	0.1667	0.25
Scenario 1- Conservative Investment	0	0	0.0625	0.125	0.1875
Scenario 2 - Aggressive Investment	0	0.04167	0.0833	0.1667	0.333

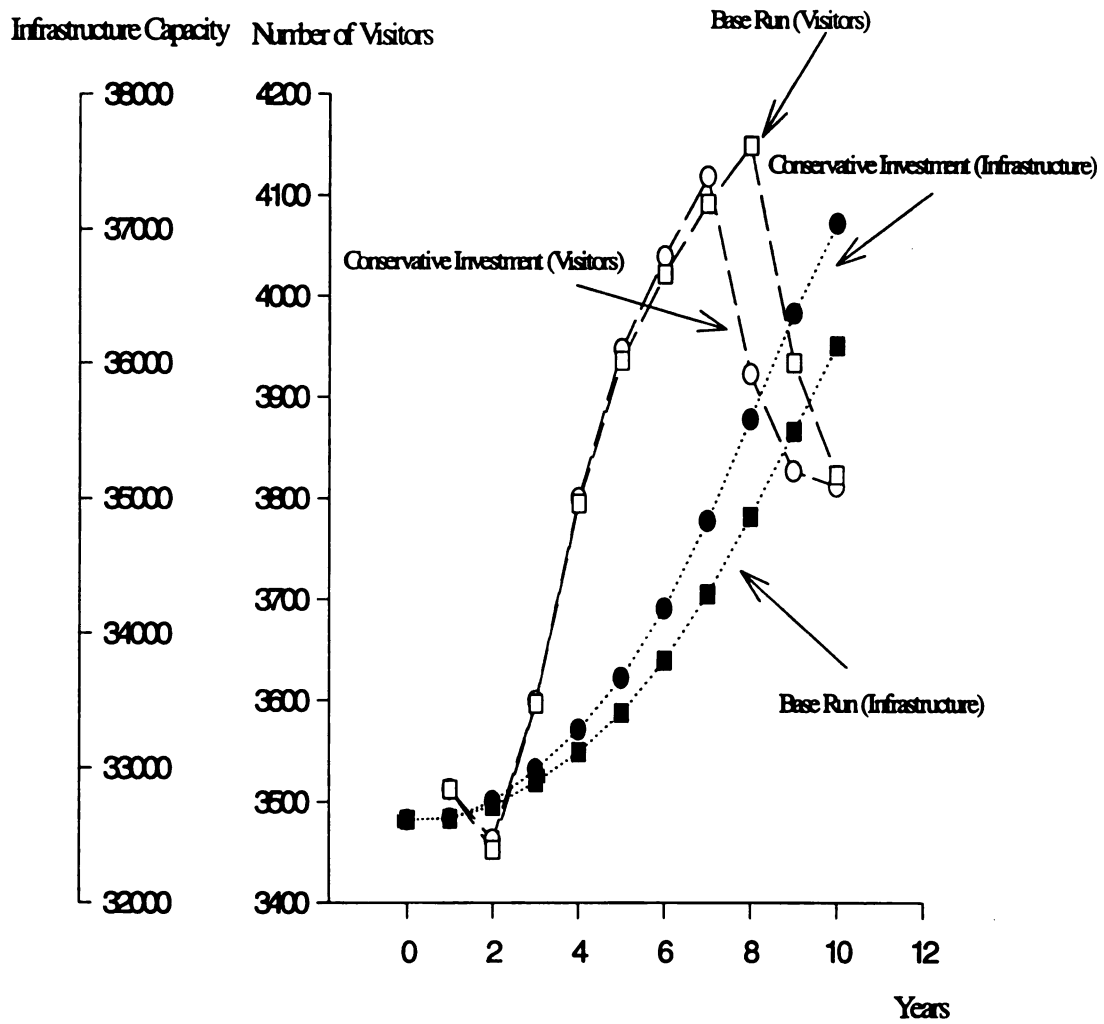


Figure 43. Comparison of the Conservative Investment and Base Run

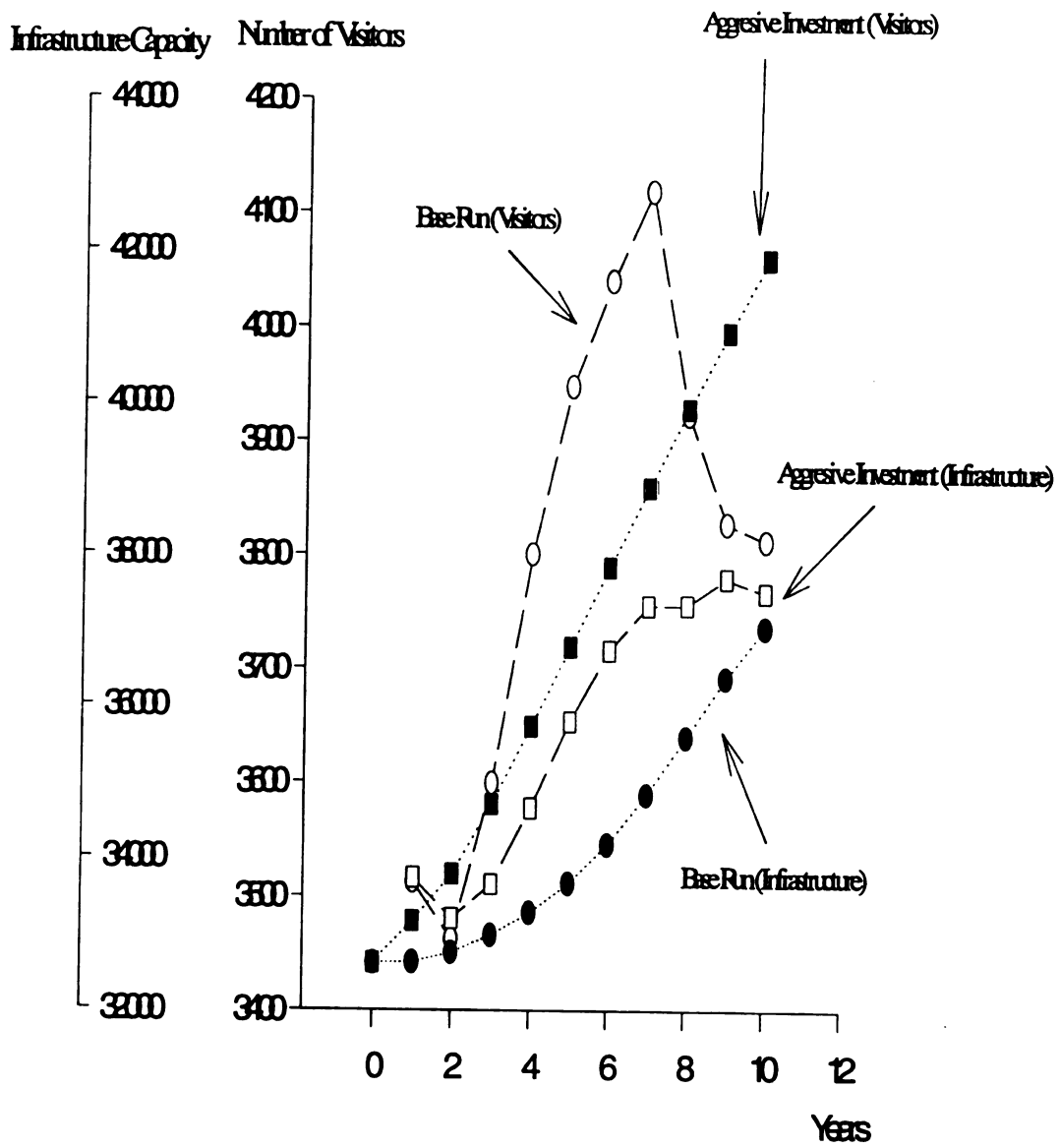


Figure 44. Comparison of the Aggressive Investment and Base Run

time period shows that the number of visitors growth of the scenario 1 is worse than the base run. However, the number of visitors growth of scenario 1 is better than base run after 7 years. These results demonstrate that the interrelationships and combinations of identified variables have a significant causal effect on the behavior of the regional system. These changes only affect one sub-sector of the entire model, and such sub-optimization may not represent the best alternatives for the whole system. The above tests can offer students an opportunity to observe change in system behavior under different conditions.

Policy for Superstructure Investment

Although most superstructure investment resources are contributed by the private sector, decisions regarding superstructure investment are made by public sector managers. This is an important consideration when teaching students about the consequences and decision making processes of various superstructure investment policies. The results of superstructure investment policy experimentation can be used by managers to evaluate the alternatives for encouraging or restricting private sector superstructure investment.

The decision criteria for superstructure investment are based on the average superstructure use rate. (Superstructure use rate is a function of the superstructure capacity divided by the number of visitors--see Chapter III). Decisions to increase superstructure investment are made only when the use rate reaches a specific level. These superstructure use rate levels vary across the base run, scenario 1, and scenario 2. The

original superstructure investment criteria and two new superstructure investment criteria represented by the different simulation scenarios are shown in Table 4. The data in Table 4 shows that the proportion of superstructure investment based upon average use rates ranging from 0 to 1. Scenario 1 assumes that the superstructure use rate is higher than the use rate in the base run and that public managers are willing to allow high quality private-sector superstructure investment at this higher level of use. Scenario 2 assumes that the superstructure use rate is higher than the use rate in the base run and in scenario 1, and superstructure investment is initiated by public managers only when use rates reach these much higher rates. The resulting amount of superstructure capacity, which is displayed in Figure 45, is less under scenario 2 than under scenario 1, partly because superstructure investment in scenario 2 is made only when use rates are much higher.

The unique and somewhat counter-intuitive relationship under scenario 2 between superstructure capacity and the number of visitors, displayed in Figure 46, is better understood using the simulation capability of the system model. Comparison between the base run, scenario 1, and scenario 2 helps to demonstrate that as decision makers raise investment criteria (i.e. investment at higher superstructure use rates), the amount of superstructure capacity is reduced. Because scenario 2 has higher investment criteria, it takes longer for investment levels to reach those displayed under scenario 1, and less superstructure capacity is developed as a result. This relationship is clearly shown in Figure 46. However, despite lower superstructure capacity, the number of visitors is

higher under scenario 2 than under scenario 1. This unique relationship indicates to students that other factors must influence the number of visitors and associated superstructure use rates. In this model, additional variables affecting the number of visitors include superstructure level of services as well as regional attractiveness. The model's superstructure causal loop and related variables are illustrated in Figure 7 and explained in Chapter III. The simulation model effectively teaches students, for example, that the conservative development of superstructure capacity can encourage a higher level of services that appeal to and attract park visitors.

Table 4. The Superstructure Investment Criteria

Testing Items	If Average Use Rate (0 - 1)			
	0.3	0.4	0.5	0.6
(Investment Parameter)				
Base Run	0.08333	0.1667	0.25	0.3333
Scenario 1	0	0.08333	0.1667	0.25
Scenario 2	0	0	0.1667	0.0833

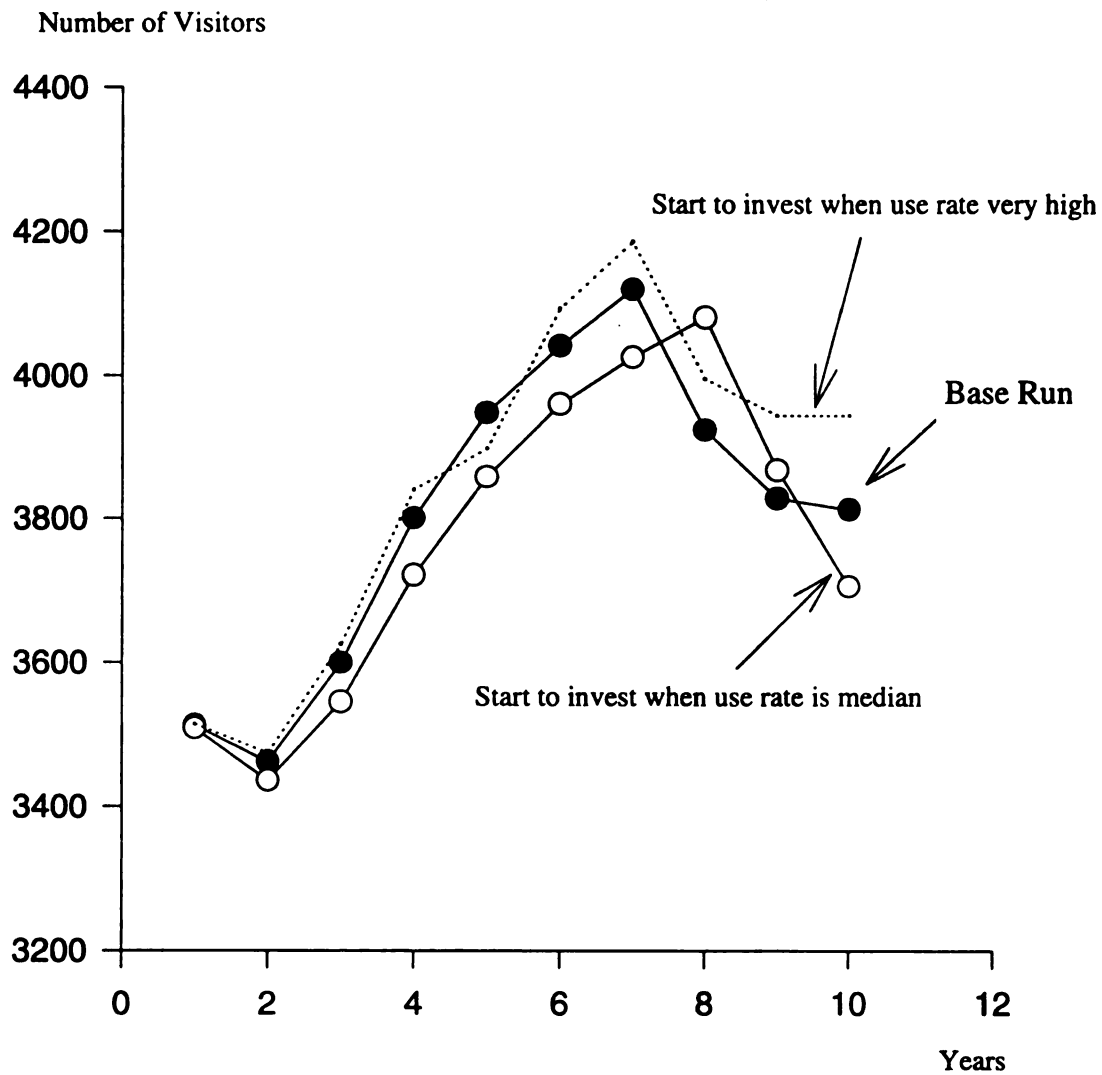


Figure 45. Comparison of Number of Visitors under Alternative Superstructure Investment Criteria

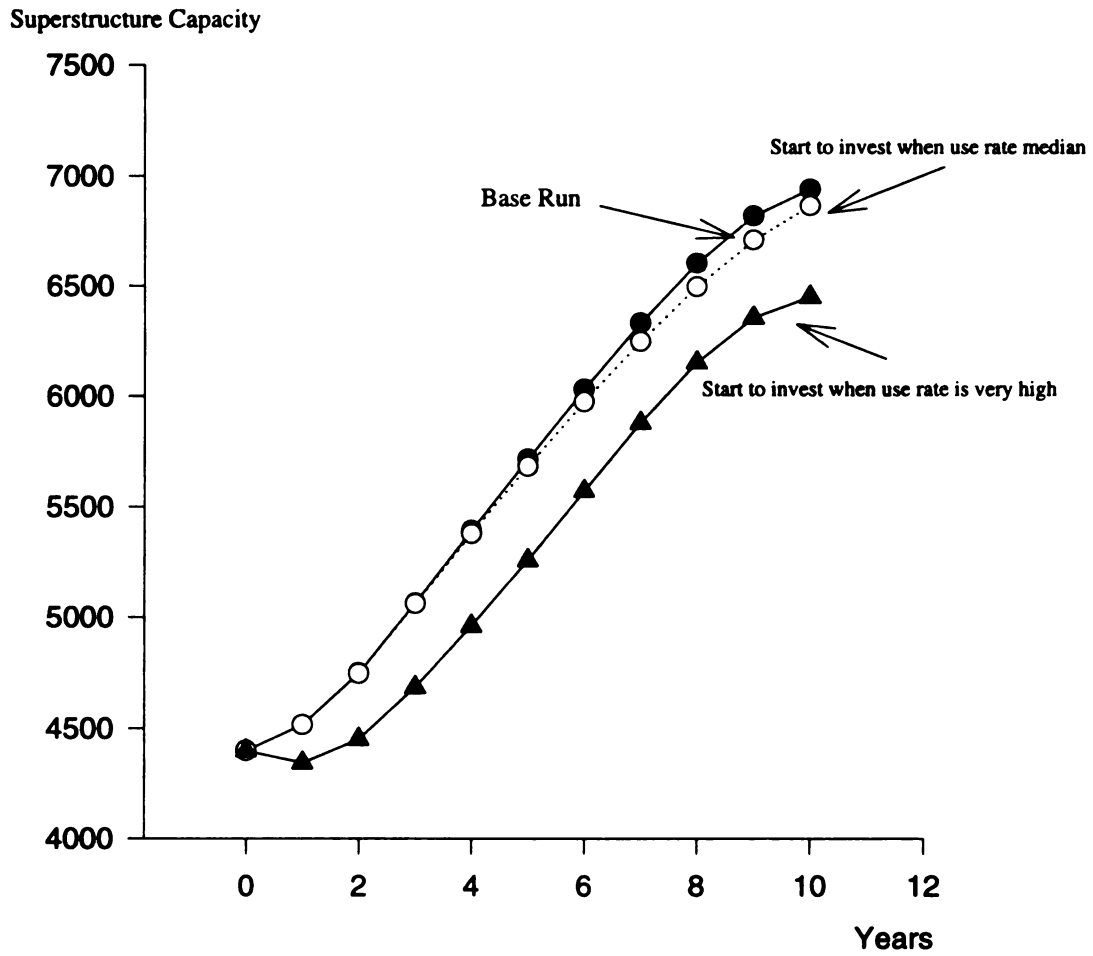


Figure 46. Comparison of Superstructure Capacity under Alternative Investment Criteria

Academic Programs in National Park Regional System Dynamics

Natural resource management can be viewed as the organization and control of a system. The use of models to permit system behavior experiments can provide an integrating structure for the teaching of natural resource management. The use of models motivate students and provide “synthetic experiences” in policy making. The study of National Park regional System Dynamics can be introduced at the beginning of an undergraduate academic program and continue through doctoral and executive development programs. At the Master’s and doctoral thesis levels, it provides a means for experimenting with new hypotheses and concepts of natural resource management organization and policy.

National Park regional System Dynamics in the natural resource management curriculum integrates the other subject matter of natural resource or recreation management. It ties together functional areas and adds the time dimension by creating an understanding of growth and of system-created change in natural resource operations.

System Dynamics and the National Park regional models introduce causal effect feedback within the educational process. As an idea is developed, it can be set up immediately as an experiment, and the results can be evaluated and revised. This sequence of invention, experiment, evaluation, and review is facilitated by the modeling process described in Chapter I through Chapter IV.

This work provides an environment and teaching tools that make it possible to observe and evaluate personal characteristics and learning styles of students in ways that are not always available in traditional classroom environments. To convert knowledge into a dynamic model, students must identify a problem, visualize the dynamic concepts which are at work, show initiative and judgment in selecting factors that must be incorporated, cope with uncertainty and incomplete information, and supply inventiveness in seeking system improvements.

Using this Study as an Instructional Tool

This study provides two separate but related expositions: [1] the development of concepts of National Park systems behavior, which is described in Chapters I, II, and III, and [2] a discussion of the implementation of instructional process and computer simulation applications. Natural resource management, like engineering, medicine and architecture, is a practical profession dedicated to addressing unique needs and achieving specific goals. The successful practitioner, in any profession, must be highly motivated to address these needs successfully. Providing the opportunity for students to recognize and understand these needs and associated goals as soon as possible in the learning process, through the study of and interaction with models such as the one described in this study, is vital to their success as students and practitioners.

The experimental study of the National Park regional model does not require advanced mathematical knowledge. By using the information contained in this study,

gaming simulation application, education and learning in natural resource management can begin with an understanding and application of basic Quantitative System Dynamics and Qualitative System Dynamics issues and concepts. These concepts can be readily understood through the interpretation and use of information from numerous familiar and accessible information sources, including history texts and current natural resources publications. Such educational tools enable students to focus on the most relevant educational topics and enhance motivation in the study of natural resource management, National Park options, and regional economic development.

The following three suggestions outline general instructional principles for the National Park regional System Dynamics model:

1. When implementing the National Park regional System Dynamics model, the instructor should focus on the concepts of the National Park system and how to express and interrelate the natural resource factors that comprise this system. He/She should not focus on the techniques and the methodology of System Dynamics.
2. Classroom simulation, with students playing the part of various components of the system, can be used to demonstrate the policy impacts of economic development in National Park regions. Group simulation offers a more personal and dramatic way of demonstrating and learning important concepts. Simulation also can demonstrate convincingly that prevailing environmental factors are a primary

determinant in the decision-making process. Decisions regarding the best action are often so powerfully influenced by available information that intuitive decisions by different people are surprisingly similar.

3. The availability of a modern high-speed computers with complex graphical user interfaces offers drama, vitality, and scope to experimental System Dynamics. Instructors considering using System Dynamics in their courses will likely be experienced or inexperienced modellers. Inexperienced modellers are not advised to consider System Dynamics unless they have access to a previously developed model. Even inexperienced instructors can quickly master the use of an existing System Dynamics model, such as that developed in this study, and use it effectively in their classes.

Curricular Plan

This study and the gaming simulation interface it describes can be used to enhance courses in both Park, Recreation and Tourism Resources as well as Resource Development. Relevant course topics and subjects that are addressed by the study are listed in the Figure 47.

I. Resource Management & Planning Courses	II. Tourism & Recreation Courses
a). Impact Assessment * Economic, Environmental & Social * Risk Analysis * Data Collection & Use * Case Studies b). Resource Development Policy * Policy Formation * Environmental & Economic Development * Policy Analysis * Case Studies c). Resource development Planning * Sustainable Development: System Approaches/Applied Model * Resource Evaluation & Assessment * Methods & Modeling: Simulation Analysis * Case Studies	a). Park, Recreation & Tourism Planning & Management * Environmental, Social & Economic Issues * Recreation & Tourism Subsystem Analysis & Supply * Community & Natural Resources Based Tourism * Impact Management * Developing & Sustaining Tourism * Tourism, Park & Recreation Evaluation * Recreation Land Management * Planning Models & Design Analysis * Case Studies b). Park, Recreation & Tourism Policy * Integrated Policy, Planning & Management * Policy Development & Evaluation * Administration & Management Issues * Park & Recreation System * Recreation & Tourism Economics * Regional Economics & Social Impacts * Case Studies

Figure 47. Relevant Course and Subjects Addressed by the Study

National Park regional economic development issues, such as those identified in Figure 47, are most effectively taught within lecture and discussion formats when combined with various forms of hands-on laboratory work. Such laboratory work can include concept expression of the causal feedback interrelationships, the study of more complicated systems by using the interactive gaming simulation interface, and individual and group projects in formulating models of natural resources situations. This study and gaming simulation interface can be used either for independent study or as a supplement to other classroom material and activities. In Figure 48, the curricular plan for single and multiple sessions, one semester and two semesters are demonstrated. The minimum classroom resource requirements necessary to utilize the study and the gaming simulation interface as an educational tool are listed below.

1. Powersim software (ModellData, Inc.) and an IBM-compatible personal computer with 386 or greater processor and 4MB or more random-access memory (RAM).
2. Appropriate presentation equipment, such as an overhead projector and LCD panel, to view instructor-led classroom discussion and interaction.
3. Student access to IBM-compatible personal computers and the gaming simulation software. Students could access the computer systems and/or software in the classroom, in a computer laboratory, on a network, or via other means.

Time Required	Users	Style	Subjects	Objectives
Single/Multiple Session	Instructor	Lecture (Interactive)	Describe modeling process and scenarios	Introduce modeling process and application in Natural resource and National Park regional planning processes
One Semester	Instructor & Student	Lecture & Experiment	Qualitative System Dynamics, Gaming-simulation Interface	Understand system process and variable relationships and estimate system behavior; hands-on use of the gaming simulation interface
Two Semester	Instructor & Student	Lecture & Experiment	Entire study, including System Dynamics approach , and supplementary material	Master System Dynamics modeling methodology and construct models of natural resources and park, recreation and tourism management and planning processes.

Figure 48. The Curricular Plan

Discussion regarding the modeling process and the use of the gaming simulation interface can be used on a limited basis to supplement existing course topics. For a relatively quick review of the modeling process and to demonstrate its use in a simple policy planning scenario, instructors may expose students to relevant portions of the study and provide an interactive demonstration of the gaming simulation interface in class. For

single or multiple sessions, instructors and students can read the verbal-description sections in Chapters I and II and the policy-implications section in Chapter IV. An instructor in one or two lectures, for example, could introduce the modeling process and implement a policy-implication scenario with his/her class.

For a more complete analysis and understanding of National Parks regional planning problems, teachers and students in one-semester course can read and discuss the part of the study that addresses planning/policy variables and other Qualitative System Dynamics issues. The instructor can select the model's sectors that emphasize the analysis of National Park regional problems that will help students understand the relationship between system processes and variables and test strategy design changes. In this case, the gaming simulation interface becomes a more integral part of the students' learning process--students can utilize the hands-on, experiential interface to explore different scenarios related to policy implementation and to become more knowledgeable about dynamic systems behavior.

To address all aspects of the study, including National Parks regional planning problems as well as Qualitative and Quantitative System Dynamics issues, in the most comprehensive manner, a two-semester course would offer students the best opportunity to master the material and its applications. Recommended two-semester course topics include all of the study's concepts, including model formulation, behavior, and

methodology as well as its application in National Parks and natural resources regional planning processes. A comprehensive study of these System Dynamics issues also requires the use of appropriate supplementary material, and a list of suggested readings in the Appendix A to assist instructors and students. The instructor should use primary and supplementary material regarding the modeling process and policy implications to provide students a realistic context for System Dynamics modeling and natural resources planning. By understanding all of the concepts addressed in the study and suggested readings, students will be able to create their own models to assist in natural resource and tourism, park, and recreation management and planning processes.

CHAPTER V

CONCLUSIONS

This chapter contains a summary of the preceding four chapters, conclusions drawn from the development and implementation of the model, the limitations of this study, recommendations for using it as an educational tool, and recommendations for improvement of the model. The summary includes a brief explanation of the need for effective teaching tools that enhance critical exploration and discussion in the classroom, the use of the System Dynamics model and gaming simulation, the goals and objectives of the model, and the System Dynamics modeling process used in this study.

Summary of the Study

National Parks regional planning and economic development problems facing instructors, managers, and policy makers today have become increasingly complex, ambiguous and interrelated. The traditional teaching style, lecture and discussion, often can fall short of their potential as a strategy for teaching classroom concepts. Traditional styles are especially limited when the classroom focus is on complex systems. The lecture style of teaching does not allow meaningful two-way communications between the instructor and the learners. Discussion style may address this basic communication problem. However, because it is often facilitated in a manner that does not encourage full

participation, discussion usually only engages a few students. Furthermore, analysis regarding critical thinking and exploration by students demonstrates the importance of teaching key concepts and issues within the context of real problems and concerns (Meyers, 1986.)

Thus, what is needed is a systematic and organized approach to teaching that can exercise and develop the problem solving, critical thinking, and discussion skills of students. In such an approach, concepts introduced in the classroom can be applied to real life situations or to controlled experiments. These applications can better facilitate the learning process by providing the proper analytical framework for understanding and discussion of key topics. An old Chinese proverb says, “ I hear - I forget, I see - I remember, I do - I understand.” Its message is that “hands-on” experience can be the best way to master concepts taught in the classroom.

The System Dynamics National Park regional system model was developed primarily to make learning of the regional economic development process in the natural resources area easier by providing a real world context within which learning can take place. Relationships, dynamic processes, and policy impacts are modeled so that they can be explored critically and dynamically. The model can be used for simulation experimentation and as the basis for comprehensive System Dynamics modeling and regional planning courses. In the process of gaming simulation, this model will

demonstrate for students the impact of recreation and tourism and population and natural resources issues on the regional planning and development process.

Goals of the National Parks regional planning model include aiding students in identifying key elements of economic development, understanding the interrelationship of these elements, and describing planning and development processes. In order to effectively meet these goals, a number of considerations were made when developing the model. The resulting objectives are identified below.

1. To provide sufficient tools and guides to permit the widespread use of the System Dynamics simulation model for educational uses in National Park regional planning.
2. To apply a suitable methodology for establishing an integrated model to organize expert knowledge and theory into a meaningful scheme for educational purposes.
3. To construct a dynamic, graph-based operational computer model that can simulate the process of National Park regional planning and development.

The modeling process used to develop the National Park regional system model involves two System Dynamics tools--Qualitative System Dynamics and Quantitative System Dynamics. Qualitative System Dynamics is based on creating cause and effect diagrams according to theories, academic references and rules of thumb, and using these to explore and analyze the system. Quantitative System Dynamics, the conventional and traditional modeling tool, involves deriving with system actors the shape of relationships

between all variables within the diagrams, and the calibration of parameters and the construction of simulation equations and experiments.

These System Dynamics tools were used to develop a system model consisting of multiple classifications of system interactions. These interactions provide the primary organizational framework for integrating the many diverse dimensions of the National Park region. The modeling process used to build the System Dynamics model of a hypothetical National Parks regional system and its contribution to the creation of an effective educational tool, is described below.

Qualitative System Dynamics was applied to formulate a systematic analysis of National Park systems to examine the scope of the analytical task. The process began by setting out the general assumption of the study, namely, the explicit treatment of the total recreation/tourism system of a National Park and the interrelations between recreation/tourism and its socioeconomic context. The overall system was divided into seven major sectors. These sectors were industry, recreation and tourism resources, economic, capital allocation, population, social overhead, and environment. The information was shared among these sectors. Some information needed in each sector must be produced by other sectors, and each sector could count on getting some of its basic information from other sectors. The process then identified those sectors of the system that consisted of variables that could be manipulated as part of a learning process.

The resulting organizational framework was engaged to examine the feedback and boundary of the National Parks regional system. The components in each sector and sector-to-sector information requirements are defined in a causal feedback loops diagram. The main causal feedback loops analysis was demonstrated in Chapter III. In this model, twenty-two causal feedback loops were evident in the intersector relationships of National Parks region with emphasis on tourism/recreation and economic development.

The causal effect diagrams create a forum for translating thoughts and assumptions about the system by individual actors into useable ideas which can be communicated to others. The affect is to broaden the understanding of each person by making them aware of the system as a whole and their role within it. In addition, through simulation, learners can rigorously experiment with concepts and processes regardless of their time frame. For example, students can quickly and easily manipulate various control variables to modify population size and growth or accelerate the development of tourism and recreation resources.

Quantitative System Dynamics guided the conversion of system causal feedback loops to a structural diagram that could be utilized as an effective educational tool. Powersim, an IBM personal computer program, was used to develop a structural diagram for the seven National Park region sectors and their sub-models. The structure of the system is perceived as consisting of three basic components: levels, rate, and auxiliary. Basic data were obtained to verify the parameters' values and the variables' relationships.

The structural diagram was then used to demonstrate how policies for economic development can be simulated and evaluated using the regional planning model. In order to place the policy runs in proper perspective, a basic simulation run describing the behavior of the National Parks region without policy inferences was presented and discussed. In addition, policy analysis was employed to assess the impact of variable model parameters on the behavior of the system.

The National Park regional simulation model is designed with an appropriate graphic-based gaming simulation interface. Gaming screens enable dynamic interaction between complex models and game-players who may be unfamiliar with the inner operations of the models. Through gaming screens, game-players receive information on the major variables in the National Park system. Game-players can actualize their policy changes by clicking on policy buttons or by changing the position of policy levers appearing on the game screens.

This study, the National Park regional planning model, and the gaming simulation interface can be used to create an educational tool that can be used to enhance a variety of courses in Park, Recreation and Tourism as well as Resource Development. A curricular plan and teaching procedures designed to accommodate different levels of use, as well as an example of a classroom simulation experiment, are provided to guide educators in using the study and the regional planning model in the education process.

Conclusions

This System Dynamics modeling technique was selected because it treats at a National Park region as a "system" and analyzes the relative components simultaneously. The approach can make controversial assumptions explicit, and provide a common framework for learners to develop a shared understanding of the problem. In addition, the modeling processes can illustrate basic concepts and theories, and provide a richer and deeper understanding of dynamic phenomena. Through the process of creatively exploring the basics of a subject, understanding of the subject matter is deepened, and critical thinking and problem solving skills are enhanced.

As a result, there are many different possible uses and applications of this type of model. These applications are briefly reviewed below.

1. Much of academic research in natural resource management has been following the tradition of the liberal arts and the social sciences---gathering data about the past and seeking explanations for the present. The present can use more than explanation. It needs more effective concepts for natural resource management and economic leadership. Hence, an academic program built around System Dynamics simulation model can be dramatic, challenging, and intellectually demanding. The impact on academic research in natural resources management can be vast, moving research away from mere data collection and explanation, and into a position of leadership toward the design of more effective system.

2. The main goals of this study for the gaming-simulation model player are not to have players grapple with the particular substantive issue loaded in the framework (i.e. the school system issues). Rather, the primary objective is to have the players learn enough about the National Park regional structure and economic development process to be able to design a new version, content-specific to their own needs.
3. Using the National Park regional simulation model will strengthen the educational experience in the classroom. A sound educational experience will emerge when the teacher/trainer pays attention to simple recommendations concerning preparation, operation, and leading discussion/critique.
4. Even if the model consists of complicated and complex phenomena, such as feedback, delays, and non-linearity's, which normally require very sophisticated mathematics, System Dynamics models can be created that are "user friendly." Such models can be used by instructors and students who are not modellers to explore and learn about complex systems.
5. The results of the simulation runs presented here show that the author has to a great extent managed to portray the basic patterns of behavior that can be observed during tourism/recreation and economic development. Both the assumptions expressed in the model equations and the simulated results are consistent with the descriptions given in the literature. Assessing the model

revealed certain elements that could be improved through further refinements and by gathering improved data on which to base these refinements. With the completion of these refinements, as outlined in the following sections, the model could meet minimal requirements to serve as a helpful teaching tool.

Study Limitations

This study has some limitations that should be addressed. These limitations are related to the selection and arrangement of information and variables for the model and the use of the model as an educational tool.

A primary limitation involves model testing. Many interesting scenarios can be played out by experimenting with various settings of the model parameters. The model lets students see the effects of tourism and recreation development policy decisions, combinations of economic variables, and various future developments in the National Park regions. However, the study does not exhaustively document simulation runs and sensitivity analysis. Sensitivity analysis is best facilitated as the model is applied and tested. It would be desirable to repeat sensitivity analysis for selected model variables as the model is used in the future. The result of sensitivity analysis will assist in refining and enhancing the level of confidence in the use of the National Park regional model. These results also can effectively help the instructor and student focus on the critical variables for experimentation and discussion.

An additional limitation involves an inherent problem with the use of models-- that the model users may misperceive or rely too much on a model as an actual 100% realistic reproduction of real world systems. Therefore, it must be emphasized that a model is always a simplified representation of reality that should be used as a tool in the decision making process. In this sense, the simplified nature of a model becomes its major strength by allowing the student to focus less on the least important aspects and more on the vital topics of discussion. To simplify reality is, however, not without problems. How do the users know which aspects are important and which are not? This implies that model users and instructors should be very careful and considerate of how forecasted values of variables are used in the planning process. Although the behavior pattern of a model may be accurate and reliable, there is no guarantee that simplified system representations will accurately reflect how a real-world system actually develops.

A third limitation of the model developed in this study is related to the fact that the person who learns the most from such a model tends to be the person who built it. Therefore, any strategy for introducing the use of National Park regional models as a means for gaining and conveying insight into economic and social principals should include not only the use of ready-made models, like the one presented in this study, but also the model building process itself.

Recommendations

This research represents an initial attempt to assist educators to effectively teach economic development issues regarding natural resources and National Park regional development. The comprehensive regional planning model developed requires additional work to maintain and enhance its reliability, validity, and relevance as an educational tool. These additional efforts support the use of study concepts and the gaming simulation model for other educational purposes as well, including career planning for students, professional development for educators, and academic program planning for educators and practitioners.

Additional work is recommended to enhance the continued utility of the National Parks Regional Planning Model. Although the model can be used effectively in its current form, gradual improvements can be made as better information becomes available. Ongoing activities that will improve the model are identified below.

1. The structure implemented in the system should be fully developed and tested to enable a complete assessment of the validity and reliability of the approach. A follow-up study of surveys of the National Park regions, therefore, is necessary to improve estimates of the parameters, constants, initial values, and table values.
2. Continuous model calibration is necessary to keep the model up-to-date and to accommodate changes in economic development policies and environmental conditions.

3. Efforts should be maintained to test the model in real classroom settings and other settings and uses for which the model can be of assistance to determine if the model actually performs as expected.
4. Use ongoing tests and implementation analysis to improve the model as well as the training process to help instructors understand and master its use.
5. Additional assistance is necessary to help instructors access and use the model, including the development of a user's manual.

Career Planning, Professional Development, Academic Program Planning

In addition to providing a valuable teaching and learning tool for instructors and students, the National Parks regional planning model and gaming simulation interface described in this study is particularly well suited to assist in other academic areas as well, including career planning, professional development, and academic programming.

The process of identifying and modeling associated societal and environmental factors provides for students a comprehensive view of the complex and interesting aspects, knowledge, skills, and professions that are a part of Natural Resource and National Parks regional management and planning. These insights offer valuable assistance to students as they explore career planning alternatives.

The study also enhances professional development activities for educators by directly addressing a number of evolving needs and priorities within the education

profession. By offering for educators a hands-on demonstration of an interactive, experiential learning tool, the planning model and gaming simulation interface can be used effectively to help educators perceive the benefits of alternative teaching styles. Experiential and active learning opportunities for students, which can be demonstrated and taught through appropriate professional development activities, allow students to build their own knowledge structures in their own contexts. “Constructive” professional development approaches, which include hands-on action research, group problem solving, peer interaction, and curriculum development, are encouraged by the use of the study and its gaming simulation interface. These approaches may help educators understand and focus more effectively on learner needs and outcomes.

In addition, the study can be used to help educators obtain a deeper understanding of the modeling process and National Parks regional planning issues and the most effective pedagogical approaches for teaching related concepts and topics. Incorporating key modeling concepts and the gaming simulation interface into professional development activities also encourages systems thinking among educators. Systems thinking is playing an increasingly important role in curriculum development, academic program planning, and educational reform (Sparks, 1995).

Academic program planning and curriculum development can be enhanced significantly by educators who are familiar with the modeling process and the real world application and interaction of Natural Resources and National Park regional planning

processes and variables. Properly maintained models can help academic and curricula planners understand the most critical and important issues for students to learn, and the use of such models necessitate productive interaction between educators and practitioners in the field.

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APPENDIX A: Suggested Readings

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APPENDIX B: List of Variables and Equations

In this appendix a list of variables and equations of the National Park regional model is presented. This information can help the user understand the assumptions that form the basis for simulating the consequences of alternative strategies, policies, and programs for promoting the economic and social development of the National Park region. The Appendix has been divided into four sections: level variable (), flow variable (), auxiliary variable () and constant variable (). In each section, the variables are listed alphabetically.

APPENDIX B: List of Variables and Equations

- ☐ **AccuLoadIndex**
 $\text{INIT } 0.05$
 $\frac{d}{dt} + \text{dt}^*(\text{VarRate})$
 Accumulate load index
- ☐ **CapBusServ**
 $\text{INIT } 500000$
 $\frac{d}{dt} + \text{dt}^*(\text{AddRBus})$
 $\frac{d}{dt} - \text{dt}^*(\text{OutBus})$
 Capital in Business Services (1000 Dollars)
- ☐ **CapHouServ**
 $\text{INIT } 80000$
 $\frac{d}{dt} - \text{dt}^*(\text{OutHou})$
 $\frac{d}{dt} + \text{dt}^*(\text{AddRHous})$
 Capital in Household Services (1000 Dollars)
- ☐ **CapitalPool**
 $\text{INIT } 30000$
 $\frac{d}{dt} - \text{dt}^*(\text{CapOut})$
 $\frac{d}{dt} + \text{dt}^*(\text{CapIn})$
 Regional Capital Pool (1000 Dollars)
- ☐ **CapOutputBus**
 $\text{INIT } 2$
 $\frac{d}{dt} + \text{dt}^*(\text{ChCapBus})$
 Capital Output Factor in Business Services (Yrs)
- ☐ **CapOutputHou**
 $\text{INIT } 1.25$
 $\frac{d}{dt} + \text{dt}^*(\text{ChCapHou})$
 Capital Output Factor in Household Services (Yrs)
- ☐ **ConEc**
 $\text{INIT } 0.2$
 $\frac{d}{dt} - \text{dt}^*(\text{Rate})$
- ☐ **Coun**
 $\text{INIT } 12$
 $\frac{d}{dt} + \text{dt}^*(\text{Recoun})$
 Dummy Variable
- ☐ **DemPerBus**
 $\text{INIT } 250000$
 $\frac{d}{dt} + \text{dt}^*(\text{BusIn})$
 Demand Perceived in Business Services (1000 Dollars/Yr)
- ☐ **DemPerHous**
 $\text{INIT } 250000$
 $\frac{d}{dt} + \text{dt}^*(\text{HousIn})$
- ☐ **FamilyPlanPersonnel**
 $\text{INIT } 0.1$
 $\frac{d}{dt} - \text{dt}^*(\text{FamPPRetired})$
 $\frac{d}{dt} + \text{dt}^*(\text{FamPPTrained})$
 Family Planning Personnel (1000 Persons)
- ☐ **InfraCap**
 $\text{INIT } 32620$
 $\frac{d}{dt} + \text{dt}^*(\text{IFiniRate})$
 $\frac{d}{dt} - \text{dt}^*(\text{Depreciation})$
 Persons/Day
 Infrastructure Capacity. The level of infrastructure capacity in the region is initialized as increase investment rate and decrease depreciation rate.
- ☐ **LaborOutFac**
 $\text{INIT } 5000$
 $\frac{d}{dt} + \text{dt}^*(\text{Change1})$
 Labor Output Factor in Business Services (1/Yr)
- ☐ **LOFHS**
 $\text{INIT } 4000$
 $\frac{d}{dt} + \text{dt}^*(\text{Change2})$
 Labor Output Factor in Household Services (1000 Dollar/Person/Yr)

- ☐ Manpower
 - INT 177
 - $\frac{d}{dt} + dt^*(Adjust)$
 - National Park current real employment for the management and maintenance work.
- ☐ MedPerson
 - INT 0.32
 - $\frac{d}{dt} + dt^*(MedInc)$
 - $-dt^*(MedRet)$
 - Medical Personnel (1000 Persons)
- ☐ Pollution
 - INT 100000000
 - $\frac{d}{dt} -dt^*(DecRate)$
 - $+dt^*(IncPoll)$
 - $-dt^*(DecPoll)$
- ☐ PotDevRes
 - INT 31
 - $\frac{d}{dt} -dt^*(ResDevRate)$
 - Potential recreation resources
- ☐ RAdult
 - INT 339
 - $\frac{d}{dt} +dt^*(Grow_Ad)$
 - $+dt^*(MRadit)$
 - $-dt^*(RAdead)$
 - $-dt^*(Grow_Old)$
- ☐ RChild
 - INT 316
 - $\frac{d}{dt} -dt^*(RCdead)$
 - $+dt^*(MRchild)$
 - $-dt^*(Grow_Ad)$
 - $+dt^*(Born_RCh)$
- ☐ RecResMagnitude
 - INT 31
 - $\frac{d}{dt} -dt^*(Decline)$
 - $+dt^*(ResDevRate)$
 - The level of recreation resources magnitude as the increase the developing the potential recreation resources and decline due to the resources extraction.
- ☐ RelativeWage
 - INT 0.8
 - $\frac{d}{dt} +dt^*(WRate)$
 - Relative Wags(This is taken to represent the ratio of regional average wage to national average wage)
- ☐ RHospiBed
 - INT 152
 - $\frac{d}{dt} +dt^*(RHBedInR)$
 - Urban Hospital Bed (Bed)
- ☐ ROld
 - INT 45
 - $\frac{d}{dt} +dt^*(MROld)$
 - $-dt^*(ROAdDie)$
 - $+dt^*(Grow_Old)$
- ☐ RSS
 - INT 21
 - $\frac{d}{dt} +dt^*(NRSS)$
 - $-dt^*(TLUSS_1)$
 - Student Enrolment in Rural Secondary School (Thousand Students)
- ☐ RuEnrolPrim
 - INT 110
 - $\frac{d}{dt} -dt^*(TLURS)$
 - $+dt^*(NRPS)$
 - Student Enrolment in Rural Primary School (Thousand Students)

- ☐ RuLiteracy
 - 595
 - $+dt^*(RLPIn)$
 - $-dt^*(RLPOut)$
 - $+dt^*(OMRLP)$
 - Rural Literacy Population (1000 Persons)
- ☐ RuralMuniArea
 - 7000
 - $+dt^*(RuralMaAarIncR)$
 - Rural Municipality Area (Acre)
- ☐ SLUR
 - 0.1
 - $+dt^*(SRate)$
 - Smoothed Local Unemployment Ratio
- ☐ SupCap
 - 4400
 - $-dt^*(SupDep)$
 - $+dt^*(SFHR)$
 - The level of superstructure capacity is initialized by in crease superstructure investment and decrease in depreciation.
- ☐ SupUnit
 - 6400
 - $-dt^*(UnitDepre)$
 - $+dt^*(UnitInves)$
 - Persons/Periods
 - The level of superstructure capacity equivalent is defined as increase in investment and decrease in depreciation.
The function of this variable is connecting the level of services and superstructure capacity.
- ☐ Tertiary
 - 9
 - $+dt^*(NTSE)$
 - $-dt^*(OUT)$
 - Tertiary Student Enrolment (Thousand Students)
- ☐ UAdult
 - 120
 - $+dt^*(MUadlt)$
 - $-dt^*(UAddead)$
 - $+dt^*(Grow_UAd)$
 - $-dt^*(Grow_UOld)$
- ☐ UChild
 - 112
 - $+dt^*(MUchld)$
 - $-dt^*(UCDead)$
 - $+dt^*(Born_UCh)$
 - $-dt^*(Grow_UAd)$
- ☐ UHospBed
 - 320
 - $+dt^*(UHBedInR)$
 - Urban Hospital Bed (Bed)
- ☐ ULiteracyP
 - 221
 - $+dt^*(OMULP)$
 - $-dt^*(ULPOut)$
 - $+dt^*(ULPIn)$
 - Urban Literacy Population (1000 Persons)
- ☐ UOld
 - 15.0
 - $+dt^*(MUold)$
 - $-dt^*(UOAdDie)$
 - $+dt^*(Grow_UOld)$

- ☐ UPrimS
 - 56
 - $-dt*(LeavRPrim)$
 - $+dt*(NUPS)$
 - Student Enrolment in Urban Primary School (Thousand Students)
- ☐ UrbanLand
 - 1500
 - $+dt*(UrbanLandGrow)$
 - Urban Land Area (Acre)
- ☐ USecond
 - 11
 - $+dt*(NUSS)$
 - $-dt*(TLUSS)$
 - Student Enrolment in Urbans Secondary School (Thousand Students)
- ☐ VisitorPerYear
 - 0
 - $+dt*(IncR)$
 - $-dt*(DecR)$
 - Persons
 - The annual visitors is determined by the difference between increase rate and decrease rate.
- ☒ AddRBus
 - $= DELAYMTR(AddBus, DelCap)$
 - Capital Add Business Services (1000 Dollars /Yr)
- ☒ AddRHous
 - $= DELAYMTR(AddHou, DelCapH)$
 - Capital Add Household Services (1000 Dollars /Yr)
- ☒ Adjust
 - $= DELAYMTR(AdjustRate, 2)$
 - Adjust rate when the manpower adjust rate goes through first order delay. The average delay time is 2.
- ☒ Born_RCh
 - $= RAdult*RBirthRate$
- ☒ Born_UCh
 - $= UAdult*UBirthRate$
- ☒ BusIn
 - $= DemBus-DemPerBus$
- ☒ CapIn
 - $= ExternalAid+GovSav+LoanRecR+PSav$
 - Capital Inflow
- ☒ CapOut
 - $= InfraAll+LandReformA+LoanRepayRate+SocCapAI$
 - Capital Outflow
- ☒ Change1
 - $= LaborOutFac*CLOFRBS$
 - Change in Labor Output in Business Services (1/Yr)
- ☒ Change2
 - $= LOFHS*CLOFRHS$
 - Change
- ☒ ChCapBus
 - $= CapOutputBus*ChFactor$
 - Change in Capital Output Factor in Business Services
- ☒ ChCapHou
 - $= CapOutputHou*ChFactorH$
 - Change in Capital Output Factor in Business Services
- ☒ Decline
 - $= (RecResMagnitude/AvgDecPer)*(1.2-MagIPeopFraction)$
 - Recreation resources extraction rate. It is defined as recreation resources magnitude divided by average decline time, and regarding the fraction of manpower for management. The difference between 1.2 and the fraction of management personnel demonstrates that even if the fraction of management personnel achieves 100%, the resources would decline to minimum but not all disappear.
- ☒ DecPoll
 - $= Pollution/PollAboTime$

- DecR
= IF(1.5>=Month, VisitorPerYear, 0)
Decrease rate. A dummy variable for calculating the annual visitors.
- DecRate
= DELAYINF(PrinveRate,3)
- Depreciation
= InfraCap/DepTime
Infrastructure depreciation is defined as the infrastructure capacity divided by the average of depreciation time period.
- FamPPRetired
= FamilyPlanPersonnel/FamPlanPerSerTime
Family Planning Personnel Retained Rate (1000 Persons/Yr)
- FamPPTrained
= DELAYMTR(FamPPTrainInd,FamiPlaPerTraTime)
Family Planning Personnel Trained (1000 Person/Yr)
- Grow_Ad
= RChild/DCP
- Grow_Old
= RAdult/DAP
- Grow_UAd
= UChild/DCP
- Grow_UOld
= UAdult/DAP
- HousIn
= DemHous-DemPerHous
- IFiniRate
= DELAYMTR(InvesRate,24,3)
Current finish rate of new infrastructure. It is the three order delay of investment rate.
- IncPoll
= PollProM*PollVisiM*PollNorm
- IncR
= MR*Visitors
Dummy variable for calculating the annual visitors.
- LeavRPrim
= NoSLeavUP+OutMigUprim+UPrimDrop
Total Leave Rate of Student Leave the Primary School (1000 Students /Yr)
- MedInc
= FMSCVG*GTS
Medical Personnel Increased (1000 Persons/Yr)
- MedRet
= MedPerson/ASLMP
Medical Personnel Retained (1000 Persons/Yr)
- MRadIt
= (IRMIR*UEmpMig-RUMI*IncDifMigMutl)*RAdult
Migrant to Rural, Adult (1000 Persons)
- MRchild
= MRadIt*NoChiPA
- MRold
= MRadIt*NoOldPA
- MUadIt
= IRMIU*UEmpMig*UAdult+RUMI*IncDifMigMutl*RAdult
Migration to Urban, Adult(1000 Persons/YR)
- MUchild
= NoChiPA*MUadIt
Migrant to Urban, Child (1000 Persons)
- MUold
= MUadIt*NoOldPA
Migrant to Urban, Old Adult (1000 Persons)
- NRPS
= MIN(DERPS,PERPS)
New Enrolment in Rural Primary School (1000 Students/Yr)

- NRSS
= MIN(ADERSS,PERSS)
[E] New Enrolment in Rural Secondary School (1000 Students/Yr)
- NTSE
= MIN(DTSE,PTSE)
[E] New Tertiary School Enrolment (1000 Students/Yr)
- NUPS
= MIN(DesirEnroUPrim,PossEnrolUPrim)
[E] New Enrolment in Urban Primary School (1000 Students/Yr)
- NUSS
= MIN(DEUSS,PEUSS)
[E] New Enrolment in Urban Secondary School (1000 Students/Yr)
- OMRLP
= (IRMIR*UEmpMig*RAult)*(NoChiPA+NoOldPA+1)*RLR
- OMULP
= (IRMIU*UEmpMig*UAdult)*(NoChiPA+NoOldPA+1)*ULR
- OUT
= GTS+TSDO
[E] Total Leave Rate of Student Leave the Primary School (1000 Students /Yr0
- OutBus
= CapBusServ*CapDisRatio
[E] Capital Discard in Business Services (1000 Dollars /Yr)
- OutHou
= CapHouServ*CapDisHRatio
[E] Capital Discard in Business Services (1000 Dollars /Yr)
- RAddead
= RAdult*RADeath
- Rate
= (ECStand*IncMuli)-QOL
- RCdead
= RChild*RCDeath
- Recoun
= IF(TIME>=Coun,12,0)
[E] Dummy variable
- ResDevRate
= (PotDevRes/DevPeriod)*RatioTechMan
[E] Developing rate of the potential recreation resources
- RHBedInR
= DELAYMTR(RHBedIncl,RHCDelay,3)
[E] Rural Hospital Bed Increase Rate (Bed/Yr)
- RLPIn
= NSLRPS-RULP
- RLPOut
= RDeathRate*RLR
[E] Death of Rural Literacy Population (1000 Persons/Yr)
- ROAdDie
= ROld*RODeath
- RuralMaAarIncR
= DELAYMTR(IncRuralMAreIR,DelayRMAI)
[E] Rural Municipality Area Increase Rate
- SFHR
= DELAYMTR(SINV, 24)
- SRate
= (LUnempRate-SLUR)/LUnempRTime
- SupDep
= SupCap/DepTime
[E] Superstrucutre Depreciation Rate.
- TLURS
= NSLRPS+OMRPS+RPSDO
[E] Total Leave Rate of Student Leave the Primary School (1000 Students /Yr0

- TLUSS
 - = NSLUSS+USSDO
 - Total Leave Rate of Student Leave the Secondary School (1000 Students /Yr0)
- TLUSS_1
 - = NoSLeavR+RSSDO
 - Total Leave Rate of Student Leave the Secondary School (1000 Students /Yr0)
- UAdeatd
 - = UAdult*UAdeath
- UCDeatd
 - = UChild*UCDeath
- UHBedInR
 - = DELAYMTR(UHBedIncl,UHCDelay,3)
 - Urban Hospital Bed Increase Rate (Bed/Yr)
- ULPIin
 - = NoSLeavUP+RULP
- ULPOut
 - = UDeathRate*ULR
 - Death of Urban Literacy Population (1000 Persons/Yr)
- UnitDepre
 - = SupUnit/DepTime
 - Superstructure equivalent unit depreciation equal to current superstructure equivalent divided by average depreciation time
- UnitInves
 - = DELAYMTR(SupInvR,24)
 - Fraction
 - Superstructure equivalent unit investment rate after three order delay
- UOAdDie
 - = UOld*UOdeath
- UrbanLandGrow
 - = DELAYMTR(IndULand,DdelayULAI)
 - Urban Land Area Increase Rate (Acre/Yr)
- VarRate
 - = IF(LoadIndex>=1,1/CriticalPoint, (-1)*(AccuLoadIndex/RecoveTime))
 - Rate of accumulate the load index.
- WRate
 - = (TRW-RelativeWage)/RWAT
- AcceptRResDen
 - = 1.2*RuResDensity
 - Acceptable Rural Resident Density (1000 Persons/Acre)
- AccepUrbanPopD
 - = 1.5*UrbanPopDensity
 - Acceptable Urban Population Density (1000 Person/Acre)
- Acces
 - = 1/AveConges
 - Regional Accessibility
- AddBus
 - = CapBusServ*CapAddMuti*CapAddRatio
 - Capital Add in Business Services (1000 Dollars /Yr)
- AddHou
 - = CapHouServ*CapAddHMut*CapAddRatio_1
 - Capital Add in Household Services (1000 Dollars /Yr)
- ADERSS
 - = DERSS*(1-FRSUSS)
 - Actural Desired Enrolment in Rural Secondary School (1000 Students /Yr)
- AdjustRate
 - = (PotentialManp-Manpower)/AdjustTime
 - The manpower adjust rate is defined the difference between the potential need of management personnel and current real employment.
- AduPop
 - = RAdult+UAdult

- AgrWage
= RelativeWage*AgriEmp*AverageWday*NWGAG
[E] Agricultural Wages (10000 Dollars/Yr)
- ASR
= GRAPHLINAS(SUSR,0.2,0.1,[0,0.083333,0.16667,0.25,0.3333*Min:0;Max:0.4])
- AttrDummyIndex
= RecResMagnitude*(1+SupServiceLev)/38
- AttrIndex
= SAttrDuln*CharIndex*(1-AccuLoadIndex)
[E] Attraction Index of the Region
- AveConges
= DELAYINF(Congestion, 12)
[E] Infrastructure average congestion degree is determined by the average exponential (smooth) of congestion.
- AveLoad
= DELAYINF(LoadIndex,12)
[E] Average load index is determined by the average exponential of load index.
- AveWage
= TotWage/TotEmployment
[E] Average Wages (Dollars/Person/Yr)
- BRPS
= PEBA-BudgPrim
[E] Budget for Rural Primary School (1000 Dollars/Yr)
- BRSS
= SEBA-BUSS
[E] Budget for Rural Secondary School (1000 Dollars/Yr)
- BTE
= EduBudgA*FBTE
[E] Tertiary Education Budget Allocation (1000 Dollars/Yr)
- BudgPrim
= PEBA*FBUPS
[E] Budget for Urban Primary School (1000 Dollars/Yr)
- BusEmp
= OutputBus/LaborOutFac
[E] Employment in Business Services (1000 Persons)
- BUSS
= SEBA*FracBugUSec
[E] Budget for Urban Secondary School (1000 Dollars/Yr)
- BusWage
= RelativeWage*BusEmp*AverageWday*NWBS
[E] Wages In Business Services (1000 Dollars/Yr)
- CapAddHMuti
= GRAPH(DemCapRatioH,0.5,0.5,[0.5,1,1.2,1.4*Min:0;Max:1.5])
[E] Capital Add Multiplier in Household Services
- CapAddMuti
= GRAPH(DemCapRatio,0.5,0.5,[0.5,1,1.2,1.4*Min:0;Max:1.5])
[E] Capital Add Multiplier in Business Services
- CarryCapc
= RecResMagnitude*ResCap*PeriodDays
[E] The regional carrying capacity is determined by the regional recreation resource magnitude multiplied the per unit resources carrying capacity in a given time period.
- CharIndex
= GRAPHLINAS(Month,1,1,[0.2,0.2,0.33,0.4,0.22,0.4,0.4,0.4,0.2,0.27,0.29,0.29*Min:0;Max:1])
[E] The characteristics of the region
- ChiPop
= RChild+UChild
- CocQOL
= GRAPHCURVE(ConEc,0,0.16,[1,0.53,0.2,0.11,0.08,0.05,0.01,0,0*Min:0;Max:1])
- Congestion
= 100*(Visitors/InfraCapPeriod)
[E] Persons
[E] The regional cojection is defined as the visitors is divided by the infrastructure capacity in period.

- DemBus
 - = (DMF1BS*OutputHou)+(DMF2BS*OutputBus)+SRQAG+SRQMI
 -  Demand in Business Services (1000 Dollars/Yr)
- DemCapRatio
 - = DemPerBus/OutCapacity
 -  Demand Capital Ratio in Business Services
- DemCapRatioH
 - = DemPerHous/OutCapHous
 -  Demand Capital Ratio in Household Services
- DemHous
 - = TotPOP*(DMF1HS+DMF2HS*PerCapIn)
 -  Demand in Household Service (1000 dollars/Yr)
- DERPS
 - = RChild*RLREM*(RPCIEM/15)+IF(MRchild>=0,MRchild,0)
 -  Desired Enrollment in Rural Primary School (1000 Students /Yr)
- DERSS
 - = MUchild*NoSLeavUP*ULREM*UPerCapIncEM*FPSSSEN
 -  Desired Enrollment in Urban Secondary School (1000 Students /Yr)
- DesirEnroUPrim
 - = UChild*ULREM*(UPerCapIncEM/15)+IF(MUchild>=0,MUchild,0)
 -  Desired Enrollment in Urban Primary School (1000 Students /Yr)
- DEUSS
 - = MUchild*NoSLeavUP*ULREM*UPerCapIncEM*FPSSSEN
 -  Desired Enrollment in Urban Secondary School (1000 Students /Yr)
- DTSE
 - = ROTSE+UDTSE
 -  Desired Enrollment in Urban Primary School (1000 Students /Yr)
- DURLR
 - = ULR-RLR
 -  Difference between Urban and Rural Literacy Rate
- EduBudgA
 - = SocCapAI*EduBudgAF
 -  Education Development Budget Allocation
- EduEmp
 - = PSEMP+TEEMP
 -  Educational Employment (1000 Persons)
- EduWage
 - = RelativeWage*EduEmp*AverageWday*NWageED
 -  Wages in Education (1000 Dollars/Yr)
- ExternalAid
 - = ExtAidlit*(STEP(1,0)+STEP(0.2,5)+STEP(-1.2,6))
 -  External Aid (1000 Dollars/Yr)
- FamIWage
 - = NWageF*(MedPerson+FamilyPlanPersonnel)*AverageWday
 -  Wage in Health and Family Planning (1000 Dollars/Yr)
- FamPerPopRatio
 - = FamilyPlanPersonnel/TotPOP
 -  Family Planning Personnel-Population Ratio
- FamPlanBudAllocat
 - = SocCapAI*FamPlanBAF
 -  Family Planning Budget Allocation (1000 Dollars/Yr)
- FamPPTPoss
 - = FamPlanBudAllocat/CapReqPerFPP
 -  Family Planning Personnel Trained, Possible (1000 Person/Yr)
- FamPPTrainDesir
 - = (DesirFPPerPopRatio*TotPOP-FamilyPlanPersonnel)/FPPRealizationTime
 -  Family Planning Personnel Trained, Desired (1000 Person/Yr)
- FamPPTrainInd
 - = MIN(FamPPTrainDesir,FamPPTPoss)
 -  Family Planning Personnel Trained, Indicated (1000 Persons/Yr)

- FRSUSS
= GRAPH(DURLR,0.2,[0,0.2,0.4,0.6,0.85,1*Min:0;Max:1])
[E] Fraction of Rural Student to Urban Secondary School
- FundPEXpa
= BudgPrim-MainExpUPrim
[E] Urban Primary School Expansion Fund (1000 Dollars/Yr)
- GoveEexp
= GovtEmp*PerGovEmpExp
[E] Government Expenditure (1000 Dollars/Yr)
- GovInterv
= GRAPHCURVE(ConEc,0,0.2,[1,0.65,0.33,0.2,0.19,0.03,0,0,0*Min:0;Max:1])
- GovSav
= TaxIncome-GoveEexp
[E] Government Saving (1000 Dollars/Yr)
- GovtEmp
= GRAPH(TIME,0.5,[0.8,1,1.2,1.5,1.8,2.1,2.5*Min:0;Max:3])
- GovtWage
= RelativeWage*AverageWday*NWGG*GovtEmp
[E] Wages in Goemment (1000 Dollars/Yr)
- GTS
= Tertiary/DTE
[E] Graduate of Teratry School (1000 Students/ Yr)
- HealBuAl
= SocCapAl*HealthBudgetAF
[E] Health Budget Allocation
- HousEmp
= OutputHou/LOFHS
[E] Employment in Household Services (1000 Persons)
- HousWage
= RelativeWage*HousEmp*AverageWday*NWHS
[E] Wages in Household Services (1000 Dollars/Yr)
- IncDifMigMutl
= GRAPH(IncomDiff,0,0.1,[0,0.5,1,1.5,2,3*Min:0;Max:5])
[E] Income Difference-Migration Multiplier
- IncMuli
= GRAPHCURVE(PerCapIn,0,200,[1.01,0.74,0.53,0.44,0.23,0.04,0,0,0*Min:0;Max:1.5])
- IncomDiff
= ((UPerCapIn)*(AIDRU)-(RPerCapIn))/RPerCapIn
[E] Income Difference Ratio
- IncRuralMAreIR
= IF(AcceptRResDen>=DesirRResDen,RMunicArealInc,0)
[E] Indicated Rural Municipality Area Increase Rate (Acre/Yr)
- IndULand
= IF(AccepUrbanPopD>=DesirUubanPopD,UrbanArealInc,0)
[E] Indicated Urban Land Area Increase Rate (Acre/Yr)
- InfraAl
= FracInfraAllocation*(CapitalPool/DelayCapA)
[E] Infrastructure Allocation (1000 Dollars/Yr)
- InfraCapPeriod
= InfraCap*PeriodDays
[E] Persons/Periods
[E] Infrastructure Capacity in Period.
- InvesParameter
= GRAPHCURVE(AveLoad,0.2,0.1,[1,1,1,0.73,0.27,0.06,0,0,0*Min:0;Max:1])
[E] Infrastructure Investment Parameter. It is associated with average load index.
- InvesRate
= InvesParameter*InfraCap*((Parameter/AvgInvPeriod)+(1/DepTime))
[E] Investment Rate of New Infratructure is equal to the current infrastructure capacity divided the average investment time period, and then, time the two investment parameters, and plus current depreciation.
- LaborForce
= LFParRate*TotalWorkPop
[E] Labor Force (1000 Persons)

- LandReformA
 - = $\text{FracLandRA} * (\text{CapitalPool} / \text{DelayCapA})$
 -  Land Reform Budget Allocation (1000 Dollars/Yr)
- LandValueMul
 - = $\text{GRAPH}(\text{UrbanLandValue}, 100, 100, [0.75, 0.9, 1.05, 1.2, 1.16, 1, 0.88, 0.78, 0.72, 0.65 * \text{Min}: 0.5; \text{Max}: 1.2])$
 -  Land Value Multiplier
- LFPaRate
 - = $\text{LFPRM} * \text{LFRI}$
 -  Labor Force Participation Rate
- LFPRM
 - = $\text{GRAPH}(\text{PerCapIn}, 500, 500, [1.1, 1.07, 1.05, 1.02, 1 * \text{Min}: 1; \text{Max}: 1.15])$
 -  Labor Force Participation Rate Multiplier
- LiterRate
 - = $(\text{RuLiteracy} + \text{ULiteracyP}) / \text{TotPOP}$
 -  Literacy Rate
- LoadIndex
 - = $\text{Visitors} / \text{CarryCapc}$
 -  Regional Load Index is defined as the visitors divided by carrying capacity.
- LoanRecR
 - = $\text{LoanRRlit} * (\text{STEP}(1, 0) + \text{STEP}(2, 5) + \text{STEP}(6, -1.2))$
 -  Loan Receive Rate (1000 Dollars/Yr)
- LoanRepayRate
 - = $\text{DELAYMTR}(\text{LoanRecR}, \text{LoanTime})$
 -  Loan Repayment Rate
- LUnempRate
 - = $(\text{LaborForce} - \text{TotEmployment}) / \text{LaborForce}$
 -  Local Unemployment Rate
- MagtPeopFraction
 - = $\text{Manpower} / \text{PotentialManp}$
- MainExpUPrim
 - = $\text{UPrimS} / \text{CostPrim}$
 -  Maintenance Expenditure of Urban Primary Schools (Dollars/Yr)
- MedicalPersonnelDM
 - = $\text{GRAPH}(\text{MPDR}, 0, 0.2, [1, 0.85, 0.7, 0.5, 0.3 * \text{Min}: 0; \text{Max}: 1])$
 -  Medical Personnel Deficiency Multiplier
- MedPersonDem
 - = $(\text{RHospiBed} + \text{UHospiBed}) / \text{MPBR}$
 -  Medical Personnel Demand (1000 Persons)
- MERPS
 - = $\text{RuEnrolPrim} / \text{CostPrim}$
 -  Maintenance Expenditure of Rural Primary Schools (Dollars/Yr)
- MERSS
 - = $\text{RSS} / \text{PPSMC}$
 -  Maintenance Expenditure of Rural Secondary Schools (Dollars/Yr)
- METS
 - = $\text{Tertiary} * \text{PTSMC}$
 -  Maintenance Expenditure of Teratiry School (1000 Dollars/Yr)
- MEUSS
 - = $\text{USecond} / \text{PPSMC}$
 -  Maintenance Expenditure of Urban Secondary Schools (Dollars/Yr)
- MinWage
 - = $\text{RelativeWage} * \text{MinEmp} * \text{AverageWday} * \text{NWGM}$
 -  Wages in Mining (1000 Dollars /Yr)
- Month
 - = $\text{TIME} - \text{Coun} + 12$
- MPDR
 - = $(\text{MedPersonDem} - \text{MedPerson}) / \text{MedPersonDem}$
 -  Medical Personnel Deficiency Ratio
- NoChiPA
 - = $\text{ChiPop} / \text{AduPop}$
- NoOldPA
 - = $\text{OldPop} / \text{AduPop}$

- NoSLeavR
= RSS/DSE
[E] Number of Student Leaving Rural Primary (1000 Students /Yr)
- NoSLeavUP
= $UPrimS/DurPrim$
[E] Number of Student Leaving Urban Primary (1000 Students /Yr)
- NSLRPS
= $RuEnrolPrim/DurPrim$
[E] Number of Student Leaving Rural Primary (1000 Students /Yr)
- NSLUSS
= $USecond/DSE$
[E] Number of Student Leaving Urban Primary (1000 Students /Yr)
- OldPop
= $ROld+UOld$
- OMRPS
= $IF(MRchild \geq 0, 0, -MRchild) * 6/15$
[E] Out-Migration of Rural Primary School Student (1000 Students/ Yr)
- OutCapacity
= $CapBusServ/CapOutputBus$
[E] Output Capacity in Business Services (1000 Dollars/Yr)
- OutCapHous
= $CapHouServ/CapOutputHou$
[E] Output Capacity in Household Services (1000 Dollars/Yr)
- OutMigUprim
= $IF(MUchld \geq 0, 0, -MUchld) * 6/15$
[E] Out-Migration of Urban Primary School Student (1000 Students/ Yr)
- OutputBus
= $MIN(DemPerBus, OutCapacity)$
[E] Output of Business Service (1000 Persons/Yr)
- OutputHou
= $MIN(DemPerHous, OutCapHous)$
[E] Output of Household Service (1000 Persons/Yr)
- Parameter
= $GRAPHLINAS(AveConges, 0, 0.2, [0, 0, 0.119, 0.249, 0.249, 0.249, 0.25, 0, 0] \text{ "Min:0;Max:0.3"})$
[E] Infrastructure Investment Parameter. It is associated with average congetion degree.
- ParkWage
= $RelativeWage * AverageWday * NWGP * Manpower$
[E] Wages in National Park (1000 Dollars/Yr)
- PEBA
= $EduBudgA * FPEBA$
[E] Primary Education Budget Allocation (1000 Dollars/Yr)
- PerCapIn
= $TotWage/TotPOP$
[E] Per Capita Income (Dollars/Person/Yr)
- PERPS
= $NSLRPS + OMRPS + RPSDO + RPSE$
[E] Possible Enrollment in Rural Primary School (1000 Students /Yr)
- PersonIncomeTax
= $TotWage * PersonIncomeTaxRate$
[E] Personal Income Tax (1000 Dollars/Yr)
- PERSS
= $NoSLeavR + RSSDO + RSSE$
[E] Possible Enrollment in Urban Secondary School (1000 Students /Yr)
- PEUSS
= $NSLUSS + USSDO + USSE$
[E] Possible Enrollment in Urban Secondary School (1000 Students /Yr)
- PollAboTime
= $GRAPH(PolluRate, 0, 10, [0.6, 2.5, 5, 8, 11.5, 15.5, 20] \text{ "Min:0;Max:20"})$
[E] Pollution Absorption Time
- PollProM
= $GRAPHCURVE(PerCapIn, 0, 2000, [0.07, 0.15, 0.25, 0.4, 0.56, 0.74, 0.99, 0.86, 1] \text{ "Min 0,Max 1"})$
[E] Pollution from Production Multiplier

- PolluRate
= Pollution/PoliStandard
- PolVisiM
= GRAPHCURVE(Visitors,0,200,[0.03,0.01,0,0.1,0.2,0.28,0.39,0.57,1*Min:0;Max:1*])
☐ Pollution from Tourism Multiplier
- PossEnrolUPrim
= NoSLeavUP+OutMigUpriM+UPrimDrop+UPrimExpan
☐ Possible Enrollment in Urban Primary School (1000 Students /Yr)
- PotentialManp
= RecResMagnitude/PerManRes
☐ The potential manpower management personnel is determined by the recreation resources magnitude divided by the maintenance ability per manpower.
- Potenvisit
= AttrIndex*AttVisitor
- PriInveRate
= PrivInves/10
- PrivateSavingR
= GRAPH(UPerCapIn,500,500,[0.01,0.02,0.035,0.055,0.08*Min:0;Max:0.1*])
☐ Private Saving for Reinvestment Rate
- PrivInves
= IF(QOL>=QolPoll, 0, GovInterv)
☐ Investment on Pollution Abatement from Private
- PSav
= PrivateSavingR*TotWage
☐ Private Saving (1000 Dollars/Yr)
- PSEMP
= (RuEnrolPrim+RSS+UPrimS+USEcond)/ASPEDP
☐ Primary-Secondary Educational Employment (1000 Persons)
- PTSE
= GTS*TEE*TSDD
☐ Possible Tertiary School Enrolment (1000 Students /Yr)
- QOL
= CocQOL*QOLIncome*QolPoll*QOLStand
- QOLIncome
= GRAPHCURVE(PerCapIn,0,2000,[0.03,0.13,0,0.14,0.35,0.69,0.91,0.97,1*Min:0;Max:1*])
☐ Quality of Life From Income Increase
- QolPoll
= GRAPHCURVE(PolluRate,0,10,[1.12,0.52,0.3,0.22,0.18,0.09,0*Min:0;Max:1.5*])
☐ Quality of Life from Pollution
- RDeathRate
= RAded+RCdead+ROAdDie
☐ Rural Population Death Rate
- RDTSE
= NoSLeavR*RLREM*FSSGTEN*RPCIEM
☐ Demand for Tertiary School Education, Rural (1000 Students/Yr)
- RealPropertyTax
= LandTax+TaxHous
☐ Real Property Tax (1000 Dollars/Yr)
- RHBdIncl
= MIN(RuralHBInclRD,RHBIRP)
☐ Urban Hospital Bed Increase Ratio, Indicated (Bed/Yr)
- RHBIRP
= RuralHBCapRat*HealBuAI/CostPerRHospBed
☐ Urban Hospital Bed Increase Rate, Possible (Bed/Yr)
- RHBPR
= RHospiBed/RPOP
☐ Rural Hospital Bed Population Ratio (Bed/1000 Persons)
- RLaborForce
= RLFPR*TotalRWorkPop
- RLFPR
= LFRPM*RLFPRI

- RLR
= $RLP1/RPOP$
[R] Rural Literacy Rate
- RLREM
= $GRAPH(RLR, 0, 0.2, [0.4, 0.7, 0.95, 0.98, 0.99, 1] * \text{Min:0;Max:1})$
[R] Rural Literacy Rate-Education Multiplier
- RMunicAreaInc
= $(RPOP/RuResDensity) * (RuralMuniArea/1.2)$
[R] Rural Municipality Area Increase (Acre/Yr)
- RPCIEM
= $GRAPH(RLR, 500, 500, [0.9, 0.98, 0.99, 0.995, 1] * \text{Min:0.9;Max:1})$
[R] Rural Per Capita Income-Education Multiplier
- RPerCapIn
= $(AgrWage + MinWage)/RPOP$
[R] Rural Per Capita Income (Dollars/Person/Yr)
- RPOP
= $RAduIt + RChild + ROld$
- RPSDO
= $RuEnrolPrim * RPSDORN$
[R] Rural Primary School Drop out (1000 Students)
- RPSE
= $DELAYINF(RPSEI, DPSD)$
[R] Rural Primary School Expansion (1000 Students /Yr)
- RPSEF
= $BRPS-MERPS$
[R] Rural Primary School Expansion Fund (1000 Dollars/Yr)
- RPSEI
= $RPSEF/PPSFC$
[R] Urban Primary School Expansion, Indicated (1000 Students/Yr)
- RSSDO
= $RSS * RSSDORN$
[R] Rural Secondary School Drop out (1000 Students)
- RSSE
= $DELAYINF(RSSEI, DSSD)$
[R] Rural Secondary School Expansion (1000 Students /Yr)
- RSSEF
= $BRSS-MERSS$
[R] Rural Secondary School Expansion Fund (1000 Dollars/Yr)
- RSSEI
= $RSSEF/PSSFC$
[R] Rural Primary School Expansion, Indicated (1000 Students/Yr)
- RSUSS
= $DERSS * FRUSS$
[R] Rural Student to Urban Secondary School (1000 Students /Yr)
- RULP
= $RUM * RUSE * RUTE$
- RUM
= $(RUMI * IncDifMigMuti * RAduIt) * (1 + NoChiPA + NoOldPA)$
[R] Rural-Urban Migration (1000 Persons/Yr)
- RuralHBIncRD
= $((DesirRuralHBPopRatio * RPOP - RHospiBed)/RuralHDRT) * (MedicalPersonnelDM)$
[R] Urban Hospital Bed Increase Rate, Desired (Bred/Yr)
- RuResDensity
= $RPOP/RuralMuniArea$
[R] Rural Resident Density (1000 Persons/Acre)
- RUSE
= $NUSS * (RSUSS/DEUSS)$
- RUTE
= $NTSE * (RDTSE/DTSE)$
- SAttrDuln
= $DELAYINF(AttrDummyIndex, 12)$

- SEBA
= EduBudgA*FSEBA
[E] Secondary Education Budget Allocation (1000 Dollars/Yr)
- ServiceEmp
= FamilyPlanPersonnel+MedPerson+Manpower+BusEmp+EduEmp+GovtEmp+HousEmp+TranspotEmp
[E] Service Employment (1000 Persons)
- SerWage
= BusWage+EduWage+GovtWage+HousWage+ParkWage+TransWage+FamiWage
[E] Service Wages (1000 Dollars/Yr)
- SINV
= ASR*SupCap/AvgInvPeriod
- SocCapAl
= FraSOA*(CapitalPool/DelayCapA)
[E] Social Overhead Allocation (1000 Dollars/Yr)
- SupCapPerProd
= SupCap*PeriodDays
- SupInvPar
= GRAPH(SUSR,0.2,0.1,[0,0.083333,0.25,0.4583,0.666*Min:0;Max:0.7])
[E] Fraction
[E] Superstructure investment parameter. The variable is defined by means of a graphical function. The assumption of how large fraction of superstructure use rate as a function of the investment decision is entered in the model by means of a graphical curve. The user can simply change the shape.
- SupInvR
= SupInvPar*SupCap/AvgInvPeriod
[E] Superstructure equivalent investment rate is determined by superstructure investment parameter times superstructure capacity divided by average investment time period
- SupInvRate
= SupInvPar*(SupCap/AvgInvPeriod)
- SupServiceLev
= SupUnit/SupCap
- SUSR
= DELAYINF(UseRate,6)
[E] Superstructure use rate goes through an average exponential time delay and responses to investment parameter.
- TarWage
= TRW1/NAWAGE
[E] Target Wage (Dollars/Person/Day)
- TaxIncome
= PersonIncomeTax+ProductTax+RealPropertyTax
[E] Tax Income of Government (1000 Dollars/Yr)
- TEE
= DELAYINF(TEEI,DTED)
[E] Tertiary Education Expansion (1000 Students/Yr)
- TEEF
= BTE-METS
[E] Tertiary Education Expansion Fund (1000 Dollars/Yr)
- TEEI
= TEEF/PTSFC
[E] Tertiary Education Expansion, Indicated (1000 Students/Yr)
- TEEMP
= Tertiary*ASPTEDP
[E] Tertiary Education Employment (1000 Persons)
- TotalRWorkPop
= RChild/3+RAduIt+ROld
- TotalWorkPop
= ChiPop/3+AduPop+OldPop
- TotEmployment
= AgriEmp+BusEmp+MinEmp+ServiceEmp
[E] Total Employment (1000 Persons)
- TotPOP
= RPOP+UPOP
[E] Total Population (1000 Persons)

- TotWage
= AgrWage+BusWage+MinWage+SerWage
📄 Total Wages (1000 Dollars/Person/Yr)
- TransWage
= RelativeWage*AverageWday*NWGTR*TranspotEmp
📄 Wages in Transportation (1000 Dollars /Yr)
- TRW
= IF(TarWage>MiWage,TRW1,TRW2)
📄 Target Relative Wage
- TRW1
= TRWA+(TRWB*AveWage)+(TRWC*SLUR)
📄 Target Relative Wage 1
- TRW2
= MiWage/NAWAGE
📄 Target Relative Wage 2
- TSDO
= Tertiary*TSDORN
📄 Tertiary Student Drop-out (1000 Students)
- UCenLaValue
= IF(UrbanPopDensity>DesirUubanPopD,UCenReaLV,UCenterLVN)
📄 Urban Center Land Value (Dollars/Acre)
- UCenReaLV
= UCenterLVN*(UrbanPopDensity/DesirUubanPopD)
📄 Urban Center Land Value, Acture (Dollars/Acre)
- UDeathRate
= UAdead+UCDead+UOAdDie
📄 Urban Population Death Rate
- UDTSE
= NSLUSS*ULREM*FSSGTEN*UPerCapIncEM
📄 Demand for Tertiary School Education, Urban (1000 Students/Yr)
- UEmpMig
= IF(SLUR>=CLUR1, UEPRM1, UEPRM2)
📄 Unemployment Ratio-Migration Multiplier
- UEPRM1
= GRAPH(SLUR,0.02,0.06,[0.25,0.7,1.2,1.5*Min:0;Max:2])
📄 Unemployment Ratio-Migration Multiplier 1
- UEPRM2
= IF(SLUR>=CLUR2, 0, UEPRM3)
📄 Unemployment Ratio-Migration Multiplier 2
- UEPRM3
= GRAPH(SLUR,-0.2,0.06,[-1.2,-0.8,-0.5,-0.2*Min:-1.5;Max:0])
- UHBedIncl
= MIN(UHBIRD,UHBIRP)
📄 Urban Hospital Bed Increase Ratio, Indicated (Bed/Yr)
- UHBIRD
= ((DUHBPR*UPOP-UHospiBed)/UHDRT)*(MedicalPersonnelDM)
📄 Urban Hospital Bed Increase Rate, Desired (Bred/Yr)
- UHBIRP
= UrbanHBCapRatio*HealBuA/CPUHB
📄 Urban Hospital Bed Increase Rate, Possible (Bed/Yr)
- UHBPR
= UHospiBed/UPOP
📄 Urban Hospital Bed Population Ratio (Bed/1000 Persons0)
- ULR
= ULiteracyP/UPOP
📄 Urban Literacy Rate
- ULREM
= GRAPH(ULR,0,0.2,[0.4,0.7,0.95,0.98,0.99,1*Min:0;Max:1])
📄 Urban Literacy Rate-Education Multiplier
- UPerCapIn
= (BusWage+SerWage)/UPOP
📄 Urban Per Capita Income (Dollars/Person/Yr)

- UPerCapIncEM
= GRAPH(ULR,500,500,{0.9,0.98,0.99,0.995,1*Min:0.9;Max:1*})
[E] Urban Per Capita Income-Education Multiplier
- UPOP
= UAdult+UChild+UOld
[E] Urban Population (1000 Persons)
- UPrimDrop
= UPrimS*UPrimDropR
[E] Urban Primary School Drop out (1000 Students)
- UPrimExpan
= DELAYINF(UPSEI,DPSD)
[E] Urban Primary School Expansion (1000 Students /Yr)
- UPSEI
= FundPExp/PPSFC
[E] Urban Primary School Expansion, Indicated (1000 Students/Yr)
- UrbanAreaInc
= LandValueMul*UrbanAreaIncN
[E] Urban Area Increase (Acre)
- UrbanLandValue
= UCenLaValue*(EXP(-Distance*UrbanRadius))
[E] Urban Land Value (Dollars/Acre)
- UrbanPopDensity
= UPOP/UrbanLand
[E] Urban Population Density (1000 Person/Acre)
- UrbanRadius
= SQRT(UrbanLand/314.16)
[E] Urban Radius (Mile)
- UseRate
= AveUserRatio*Visitors/SupCapPerProd
- USSDO
= USecond*USSDORN
[E] Urban Secondary School Drop out (1000 Students)
- USSE
= DELAYINF(USSEI,DSSD)
[E] Urban Secondary School Expansion (1000 Students /Yr)
- USSEF
= BUSS-MEUS
[E] Urban Secondary School Expansion Fund (1000 Dollars/Yr)
- USSEI
= USSEF/PSSFC
[E] Urban Primary School Expansion, Indicated (1000 Students/Yr)
- Visitors
= MIN(InfraCapPeriod,Potenvisit)
[E] The visitors can be expressed by the comparison of infrastructure capacity and potential visitors. In other words, if the infrastructure capacity is available for the potential visitors, the potential visitors will be the visitors.
- ◇ AdjustTime
= 1
[E] The manpower gaps' average adjust time.
- ◇ AgriEmp
= 150
[E] Employment in Agriculture (1000 Persons)
- ◇ AIDRU
= 0.75
[E] Acceptable Income Difference between Urban and Rural
- ◇ ASLMP
= 35
[E] Average Service Life of Medical Personnel (Yr)
- ◇ ASPEDP
= 24
[E] Average Students per Primary Education Personnel (Students/Person)

- ◇ ASPTEDP
 - = 15
 -  Average Students per Tertiary Education Personnel (Students/Person)
- ◇ AltVisitor
 - = 560000
- ◇ AverageWday
 - = 260
 -  Average Numbers of Working Days (Days/Yr)
- ◇ AveUserRatio
 - = .2
 -  Average proportion of visitors using the superstructure
- ◇ AvgDecPer
 - = 60
 -  Average resources decline time period
- ◇ AvgInvPeriod
 - = 12
 -  Average Investment Rate. Investment does not always occur as immediately response to infrastructure or superstructure lacking.
- ◇ CapAddRatio
 - = 0.06
 -  Capital Add Normal in Business Services (1/Yr)
- ◇ CapAddRatio_1
 - = 0.05
 -  Capital Add Normal in Household Services (1/Yr)
- ◇ CapDisHRatio
 - = 0.04
 -  Capital Discard Ratio in Business Services (1/Yr)
- ◇ CapDisRatio
 - = 0.04
 -  Capital Discard Ratio in Business Services (1/Yr)
- ◇ CapReqPerFPP
 - = 7500
 -  Capital Requirement Per Family Planning Personnel (1000 Dollars/Person)
- ◇ ChFactor
 - = 0.01
 -  Change in Capital Output Factor Normal in Business Services
- ◇ ChFactorH
 - = 0.04
 -  Change in Capital Output Factor Normal in Household Services
- ◇ CLOFRBS
 - = 0.01
 -  Change in Labor-Output Factor Ratio in Business Service (1/Yr)
- ◇ CLOFRHS
 - = 0.01
 -  Change Labor Output Factor Ratio in Household Services
- ◇ CLUR1
 - = 0.02
 -  Critical Local Unemployment Ratio 1
- ◇ CLUR2
 - = -0.02
 -  Critical Local Unemployment Ratio 2
- ◇ CostPerRHospBed
 - = 5
 -  Cost Per Urban Hospital Bed (1000 Dollars/Bed)
- ◇ CostPrim
 - = 70
 -  Per Primary Student Maintenance Cost (Dollars/Student)
- ◇ CPUHB
 - = 7
 -  Cost Per Urban Hospital Bed (1000 Dollars/Bed)

- ◇ CriticalPoint
= 12
 The critical time period of overuse the resources
- ◇ DAP
= 50
 Duration of Adult Period (Yrs.)
- ◇ DCP
= 15
 Duration of Childhood Period (Yrs.)
- ◇ DdelayULAI
= 2
 Delay of Urban Land Area Increasing (Yr)
- ◇ DelayCapA
= 0.5
 Delay on Capital Allocation (Yr)
- ◇ DelayRMAI
= 1.5
 Delay of Rural Municipality Area Increasing (Yr)
- ◇ DelCap
= 2
 Delay in Capital Add Realization in Business Services (Yrs)
- ◇ DelCapH
= 2
 Delay in Capital Add Realization in Household Services (Yrs)
- ◇ DepTime
= 120
 Years
 Average depreciation time period.
- ◇ DesirFPPerPopRatio
= 0.0005
 Desired Family Planning Personnel Population Ratio
- ◇ DesirRResDen
= 0.1
 Desired Rural Residential Density (1000 Persons/Acre)
- ◇ DesirRuralHBPopRatio
= 1.35
 Desired Urban Hospital Bed Population Ratio (Bed/1000 Persons)
- ◇ DesirUubanPopD
= 0.2
 Desired Urban Population Density (1000 Person/Acre)
- ◇ DevPeriod
= 150
 Resources developing time period.
- ◇ Distance
= 2.5
 Distance Constant Specifing the Land Value Change
- ◇ DMF1BS
= 0.2
 Demand Factor in Business Service
- ◇ DMF1HS
= 20
 Demand Factor 1 in Household Service
- ◇ DMF2BS
= 0.3
 Demand Factor in Business Service
- ◇ DMF2HS
= 0.06
 Demand Factor 2 in Household Service
- ◇ DMPTBS
= 2
- ◇ DMPTHou
= 2

- ◇ DPSD
= 1.5
[E] Delay in Primary School Development (Yr)
- ◇ DSE
= 4
[E] Duration of Secondary Education (Yr)
- ◇ OSSD
= 2
[E] Delay in Secondary School Development (Yr)
- ◇ DTE
= 4
[E] Duration of Teratiry Education (Yr)
- ◇ OTED
= 3
[E] Delays in Tertiary Education Development (Yr)
- ◇ DUHBPR
= 1.35
[E] Desired Urban Hospital Bed Population Ratio (Bed/1000 Persons)
- ◇ DurPrim
= 6
[E] Duration of Primary Education (Yr)
- ◇ ECStand
= 0.5
- ◇ EduBudgAF
= 0.75
[E] Education Development Budget Allocation Fraction
- ◇ ExtAidIti
= 6680
[E] External Aid, Initial (1000 Dollars/Yr)
- ◇ FamiPlaPerTraTime
= 0.5
[E] Family Planning Personnel Training Time (Yr)
- ◇ FamPlanPerSerTime
= 35
[E] Family Planning Personnel Service Time (Yr)
- ◇ FBTE
= 0.3
[E] Fraction of Tertiary Education Budget Allocation
- ◇ FBUPS
= 0.4
[E] Fraction of Budget for Urban Primary School
- ◇ FlamPlanBAF
= 0.1
[E] Family Planning Allocation Fraction
- ◇ FMSCVG
= 0.03
[E] Fraction of Medical Students in College and Vocational Graduates
- ◇ FPEBA
= .38
[E] Fraction of Primary Education Budget Allocation
- ◇ FPPRealizationTime
= 2
[E] Family Planning Personnel Realization Time (yr)
- ◇ FPSEN
= 0.75
[E] Fraction Primary Student to Secondary Education Normal
- ◇ FracBugUSec
= 0.4
[E] Fraction of Budget for Urban Secondary School
- ◇ FracInfraAllocation
= 0.4
[E] Fraction of Infrastructure Allocation

- ◇ FracLandRA
= 0.5
[B] Fraction of Land Reform Allocation
- ◇ FraSOA
= 0.35
[B] Fraction of Social Overhead Allocation
- ◇ FSEBA
= .32
[B] Fraction of Secondary Education Budget Allocation
- ◇ FSSGTEN
= 0.75
- ◇ HealthBudgetAF
= 0.15
[B] Health Budget Allocation Fraction
- ◇ IRMIR
= -0.01
- ◇ IRMIU
= -.015
[B] Inter-Regional Migration Index, Urban (Person/1000Person)
- ◇ LandTax
= 200
[B] Tax on land (1000 Dollars)
- ◇ LFRI
= .495
[B] Labor Force Participated Initial
- ◇ LoanRRInit
= 6500
[B] Loan Receive Rate, Initial (1000 Dollars/Yr)
- ◇ LoanTime
= 10
[B] Loan Time (Yr)
- ◇ LUnempRTime
= 2
[B] Local Unemployment Ratio Adjustment Time (Yrs)
- ◇ MinEmp
= 12
[B] Employment in Mining (1000 Persons)
- ◇ MinWage
= 8
[B] Minimum Wage (Dollars/Person/Day)
- ◇ MPBR
= 0.003
[B] Medical Personnel to Hospital Bed Ratio (1000 Persons /Bed)
- ◇ MR
= 1
[B] Dummy variable
- ◇ NAWAGE
= 8
[B] National Average Wage (Dollars/Person/Yr)
- ◇ NWageED
= 12
[B] Normal Wages in Education (1000 Dollars/Yr)
- ◇ NWageF
= 15
[B] Normal Wage in Health and Family Planning (Dollars/Person/Day)
- ◇ NWBS
= 9
[B] Normal Wage in Household Services (Dollars/Person/Yr)
- ◇ NWGAG
= 4.5
[B] Normal Wages in Agriculture (1000 Dollars / Yr)

- ◇ NWGG
= 12
[E] Normal Wages in Government (1000 Dollars/Yr)
- ◇ NWGM
= 9
[E] Normal Wages in Mining (1000 Dollars /Yr)
- ◇ NWGP
= 6
[E] Normal Wages in National Park (1000 Dollars/Yr)
- ◇ NWGTR
= 9
[E] Normal Wages in Transportation (1000 Dollars/Yr)
- ◇ NWHS
= 6
[E] Normal Wage in Household Services (Dollars/Pseson/Day)
- ◇ PerGovEmpExp
= 3000
[E] Per Government Employment Expendiature (Dollars/Person)
- ◇ PeriodDays
= 30
[E] The numbers of day in period.
- ◇ PerManRes
= .18
[E] Average responsibe for maintenance the recreation resource per manpower.
- ◇ PersonIncomeTaxRate
= 0.3
[E] Personal Income Tax Rate
- ◇ PollNorm
= 10000000
- ◇ PollStandard
= 200
[E] Pollution Standard
- ◇ PPSFC
= 500
[E] Per Primary Student Facility Cost (Dollars/Students)
- ◇ PPSMC
= 100
[E] Per Secondary Student Maintenance Cost (Dollars/Student)
- ◇ ProductTax
= 500
[E] Products Tax (1000 Dollars/Yr)
- ◇ PSSFC
= 600
[E] Per Secondary Student Facility Cost (Dollars/Person)
- ◇ PTSFC
= 6000
[E] Per Tertairy Student Facility Cost (Dollars/Student)_
- ◇ PTSMC
= 500
[E] Per Tertairy Student Maintenance Cost (Dollars/Student)
- ◇ QOLStand
= 1
[E] Quality of Life Standard
- ◇ RADeath
= 0.0043
[E] Death Rate of Rural Adult, Normal (1/Yr)
- ◇ RatioTechMan
= 1
[E] The fraction of the technology manpower, who is used for developing the potential recreation resources is represented by parameter. It demonstrates that not only this variable is not able to be controled by decision maker, but also it includes the idea of an execution plan.

- ◇ RBirthRate
= 0.06
- ◇ RCDDeath
= 0.0034
[B] Death Rate of Rural Children, Normal (1/Yr)
- ◇ RecoveTime
= 24
[B] If the overuse the resources, the average RECOVER TIME to back to the original resources.
- ◇ ResCap
= 1000
[B] The carrying capacity per unit resource.
- ◇ RHCDelay
= 2
[B] Rural Hospital Construction Delay (Yr)
- ◇ RLFPRI
= 0.54
- ◇ RLP1
= 221
[B] Rural Literate Population (1000 Persons)
- ◇ RODeath
= 0.044
[B] Death Rate of Rural Old Adult, Normal (1/Yr)
- ◇ RPSDORN
= 0.07
[B] Rural Primary Student Drop-out Rate
- ◇ RSSDORN
= 0.1
[B] Rural Secondary Student Drop-out Rate
- ◇ RUMI
= .01
[B] Rual-Urban Migration Index (Person/1000 Person)
- ◇ RuralHBCapRat
= 0.7
[B] Urban Hospital Bed, Capital Ratio
- ◇ RuralHORT
= 5
[B] Urban Hospital development Realization Time (Yr)
- ◇ RWAT
= 5
[B] Relative Wage Adjustment Time
- ◇ SRQAG
= 10
[B] Service Requirement in Agriculture (1000 Dollars/Yr)
- ◇ SRQMI
= 5
[B] Service Requirement in Mining (1000 Dollars/Yr)
- ◇ TaxHous
= 500
[B] Tax on Housing (1000 Dollars)
- ◇ TranspotEmp
= 500
[B] Employment in Transportation (1000 Persons)
- ◇ TRWA
= 1.1
[B] Target Relative Wage Factor A
- ◇ TRWB
= 0.0001
[B] Target Relative Wage Factor B
- ◇ TRWC
= -.2
[B] Taget Relative Wage C

- ◇ TSDORN
= 0.1
 Tertiary Student Drop-out rate
- ◇ UAdeath
= 0.0043
 Death Rate of Urban Adult, Normal (1/Yr)
- ◇ UBirthRate
= 0.058
- ◇ UCDeath
= 0.0033
 Death Rate of Urban Children, Normal (1/Yr)
- ◇ UCenterLVN
= 600
 Urban Center Land Value, Normal (Dollars/Acre)
- ◇ UHCDelay
= 2
 Urban Hospital Construction Delay (Yr)
- ◇ UHDRT
= 5
 Urban Hospital development Realization Time (Yr)
- ◇ UOdeath
= 0.0435
 Death Rate of Urban Old Adult (1/Yr)
- ◇ UPrimDropR
= 0.05
 Urban Primary Student Drop-out Rate
- ◇ UrbanAreaIncN
= 100
 Urban Area Increase, Normal (Acre)
- ◇ UrbanHBCapRatio
= 0.3
 Urban Hospital Bed, Capital Ratio
- ◇ USSDORN
= 0.08
 Urban Secondary Student Drop-out Rate
-  start = 0.00000
-  stop = 100.00000
-  dt = 1.00000
-  method = Euler (fixed step)

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