A COMPUTER ASSISTED APPROACH TO REGIONAL DEVELOPMENT

REPORT OF RESEARCH ACTIVITIES ON THE KINKI REGION OF JAPAN

HANS KNOP, Editor
MARCH 30 - APRIL 2, 1976
CP-76-10

CP-76-10

A COMPUTER ASSISTED APPROACH TO REGIONAL DEVELOPMENT

REPORT OF RESEARCH ACTIVITIES ON THE KINKI REGION OF JAPAN

HANS KNOP, Editor

MARCH 30 - APRIL 2, 1976

International Institute for Applied Systems Analysis
2361 Laxenburg, Austria

PREFACE

Japan's economic growth during the last quarter of a century has made it one of the world's leading industrial nations. Owing to the paucity of natural resources and the limited land area, this development was achieved mainly by concentrating industrial activities. As a natural outcome of this economic growth and concentration, many undesirable social problems have developed that now have been brought to public notice. In creating an industrialized region, we must now safeguard the environment and provide a satisfactory quality of life for the inhabitants of that region. This entails taking into account not only the economy of the region but also aspects such as population, resources, land use, communication, and transportation. Without the aid of a systems-analytic approach, it is almost impossible to deal with such complicated problems.

For the past several years we have had a research program for environmental pollution control, supported by the Ministry of Education in Japan, and we are now directing our efforts to developing new methods and strategies for integrated regional management using the techniques of systems analysis.

IIASA's research group on integrated regional development (IRD) and the Japanese team plan to exchange methods and results to advance their joint research.

As the object of our work, we have selected the Kinki area as a case study, since it is an economically important region in Japan. Our research group involves approximately 30 engineers and economists, and the following tasks are now under way:

- Development of systems methods for regional data collection and management;
- Model building of IRD systems;
- Construction of computer-aided systems to seek optimal regional development strategies;
- Application of multiobjective planning methods for IRD, pollution control, and water resources management problems;
- Risk assessment in regional and urban planning;
- Comparison of IRD methods for several regions, and model transfer.

As the first step of the cooperative research, a seminar on Kinki regional management was held at IIASA from March 29 to April 2, 1976, to introduce the Japanese research activities. This volume includes the presentations given at that seminar.

First, current social problems in the Kinki region are surveyed. Second, Yutaka Suzuki of Osaka University describes a system model that seeks optimal regional development patterns. This work was done under contract with the Ministry of International Trade and Industry in Japan. Third, Takayasu Matsuzaki of IBM Japan explains a regional development planning support system for local government. This computer-aided IRD system was developed for the regional decision makers of Hyogo Prefecture in the Kinki area. Last, Saburo Ikeda of Kyoto University reports on the environmental aspects of the region and briefly explains a water quality simulation model for Lake Biwa and the Yodo River.

We are publishing this report to inform other regional scientists concerned with IIASA's IRD program of our work, and we would appreciate receiving comments and suggestions on this cooperative research.

Finally, we would like here to express our sincere thanks to Roger Levien, Director of IIASA, and to Hans Knop, Chairman of the IIASA Management and Technology area, for their efforts in organizing and advancing this cooperative research.

Yoshikazu Sawaragi
Organizer and Principal Investigator
Japanese Research Group
Kyoto University

ABSTRACT

These proceedings report on the results of cooperation between the IIASA Management and Technology Area and a team of Japanese scientists from Kyoto University, Osaka University, and the IBM Center in Japan led by Y. Sawaragi. This seminar is the first in a series of meetings on research activities involving the Management and Technology Area and cooperating institutes. The work of the Japanese group is of particular interest since the Kinki region in Japan is a highly industrialized and populated region.

A computer-aided systems approach was used to assist the region's decision makers in solving problems of regional planning and development.

Three examples were discussed: a systems model, based on linear programming techniques, that deals with optimal regional development; a computer-aided planning support system based on system dynamics, input/output, and man/machine interface to aid in regional development decisions; and a water quality simulation model that utilizes a combination of dynamic, static, and linear programming techniques and is linked to the regional planning model.

TABLE OF CONTENTS

INTRODUCTION

One major activity of the IIASA Management and Technology Area is large-scale planning projects for socio-economic systems. Studies of the Tennessee Valley Authority in the USA, and the Bratsk-Ilimsk Territorial Production Complex in the USSR have been completed; currently a study is being made of regional development in Scotland. In carrying out these studies, the Management and Technology Area has cooperated with scientific institutes in the USSR, the UK, Poland, and Japan that deal with problems of regional development.

These proceedings report on the results of the Area's cooperation with a team of Japanese scientists from Kyoto University, Osaka University, and the IBM Center in Japan led by Y. Sawaragi.

This seminar is the first in a series of meetings on research activities between the Management and Technology Area and cooperating institutes. The work of the Japanese group is of particular interest to IIASA and its National Member Organizations because it was carried out in a highly industrialized and populated region.

The first activity of the Japanese group was modeling pollution processes. While trying to make the environmental models operational in the decision-making process, they learned that environmental problems can be solved only by examining the interrelationship of all elements in the regional system. This led to a broader integrated regional planning and modeling approach.

We are pleased to report on the initial results of this research, and hope that other scientific teams working in this field will join our network of research cooperation.

Hans Knop, Chairman
Management and
Technology Area

General Overview of the Kinki Region

Y. Sawaragi[†] and Y. Suzuki[††]

The Kinki region is situated a little to the west of the middle of the Japanese mainland (see Figure 1), and its name is derived from an old Japanese word that means "adjacent area of the capitol". The southern part of the region touches the Pacific Ocean, the northern part the Japanese sea. The middle portion of the region contains the largest fresh water lake in Japan, Lake Biwa.

Administratively the Kinki region is now divided into seven prefectures: Osaka, Hyogo, Kyoto, Nara, Shiga, Wakayama, and Fukui (see Figure 2). Historically the Kinki area has always been the most developed region of Japan. Almost all of the ancient capitals of Japan were placed within the Kinki region as shown in the chronography of Table 1. The world famous cities of Kyoto and Nara exhibit a large amount of historical interest even today.

Approximately 18% of the socio-economic activity of present day Japan is contained in the Kinki area, although its land area is approximately 10% of that of Japan (see Figure 3). The major part of its industrial activity is concentrated along the coastline of the Seto Inland Sea, and more than 60% of the region's population is contained in the Yodo River Basin which includes the territory surrounding Lake Biwa.

The Kinki region is now facing serious problems dealing with such topics as the shortage of land and water resources, environmental pollution, traffic and housing congestion. From the national point of view, the Kinki area is still expected to play an important role in the future socio-economic development of Japan (see Figure 4). These situations necessitate comprehensive integrated regional planning for the Kinki region.

[†] Faculty of Engineering, Kyoto University

[††] Faculty of Engineering, Osaka University

Table 1. Chronology.

Century	Capital or Political Center	Form of Society	Political Form
7	ASUKA		Ruled by influential clans
8	NARA		Governed by emperors
9		Ancient Society	
10	KYOTO		Governed by royal regents
11			Controlled by ex-emperor voice
12			
13	KAMAKURA		Ruled by military class
14		Feudal Society	
15	KYOTO		Emperor's sovereignity restored
16	AZUCHI & MOMOYAMA		Ruled by military class
17			
18	YEDO (TOKYO)	Shogunate Society	
19			Meiji restoration
20	TOKYO	Modern Society	Constitutional government

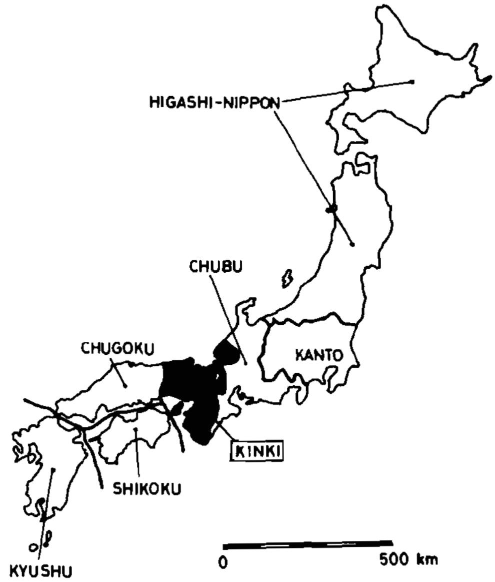


Figure 1. Administrative divisions of Japan.

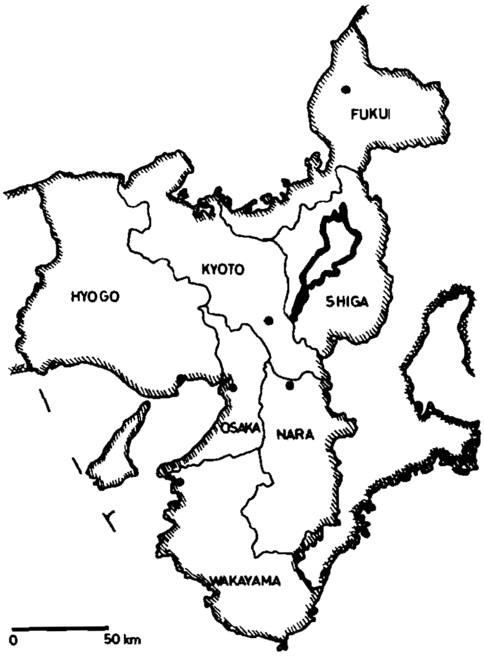


Figure 2. Administrative divisions of Kinki region.

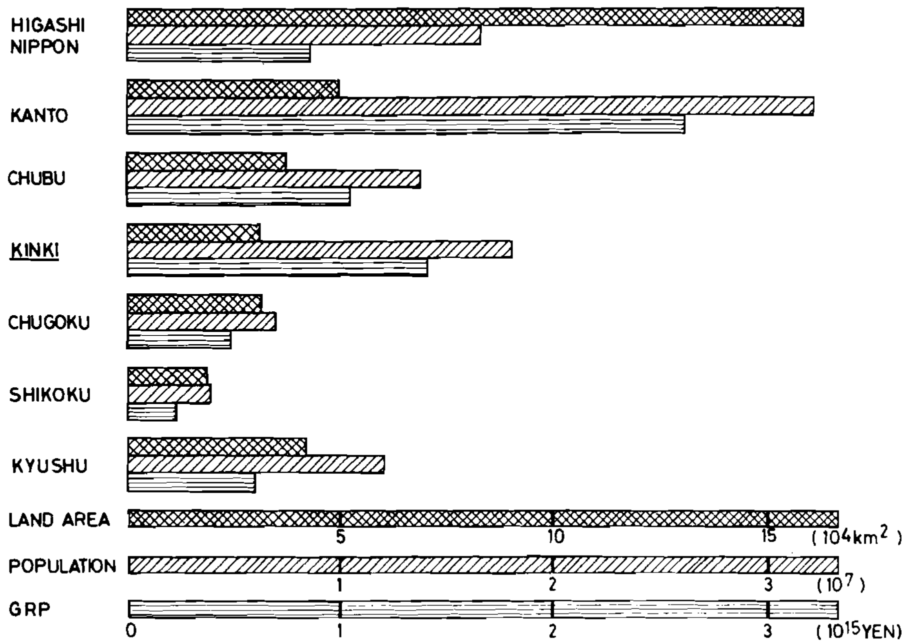


Figure 3. Comparisons of land area, population, and GRP between seven regions in Japan (1970).

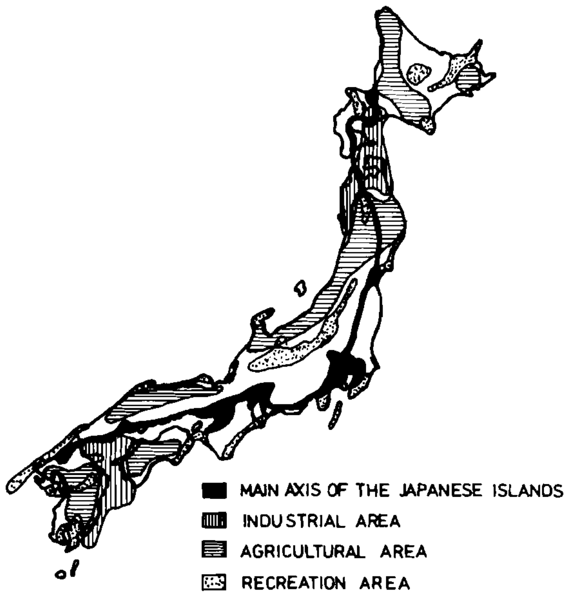


Figure 4. A plan of national land development in Japan.

An Integrated Regional Planning Model: A Case Study of the Kinki Area

Y. Suzuki[†], H. Ishitani[††], and K. Shoji[†]

INTRODUCTION

The objective of this research is to construct an integrated regional planning model for a specified region, which seeks the desirable socio-economic development pattern and strategies to realize it. The region of our concern is composed of subregions of the prefecture base (2,000 to 10,000 km^2), and the time span is over the forthcoming 20 to 30 years.

Various regional planning models have been constructed so far. Most of them are concerned with the regional economic development; their objectives have been:

- To predict the future with an econometric model which is constructed by using the historical data;
- To investigate the effectiveness of alternative policies for the regional development by simulation.

These models are directed mainly to the positive analysis of economic aspects. Also regional economic theory has been developed extensively concerning the desirable figure of a regional economy. However, the theory oriented analysis seems to have limitations when we look at the actual regional status.

As a matter of fact, many social aspects of each region are not described explicitly in the economic theory, and various problems such as environmental pollution, the shortage of water resources, traffic congestion, etc. have become very serious after rapid economic growth in these regions. Several approaches for these problems have been tried from the fields of economics, for example, public economics. However, there are many different viewpoints, even on the normative analysis of individual problems, but not all of them are well enough established to arrive at practical solutions to these problems.

[†]Faculty of Engineering, Osaka University

[††]Institute of Space and Aeronautics, University of Tokyo

In this context, we have developed a new type of integrated regional planning model where various aspects that are on the outside of economics, such as environmental pollution and the shortage of water resources, are considered explicitly. In order to reduce the constraints on the resources and the environment, it is necessary to reinvestigate the present allocation pattern of industries, population and social capital. However, it will take more than ten years for any policy adopted for the reallocation problem to have actual effects. Under these circumstances, planning over only a short range has the possibility of serious failure. Therefore, we have chosen a planning period of 30 years.

Since our period is very long, we are partly free from past trends, and our intention is to describe the various socio-economic development patterns under different premises. Generally speaking, there exists a trade-off between the complexity and the performance of a model. For the integrated model, its scale becomes necessarily large, and the burden on time and cost becomes too heavy to execute many trials. Analytical problems will also arise. To overcome this difficulty, we have adopted a hierarchical approach by using two types of models. In both models, the interested region and its surroundings are divided into several subregions, and the future regional status is investigated in relation to the future national status.

In the upper stratum of the model, only two time points of the initial and final years are considered. A linear programming model has been used to determine the optimum allocation of industries, population, and social capital under several premises, (for example, GNP growth, accumulated capital investments, etc.). This model puts emphasis on the operational characteristics, saving the computational time, and can describe various socio-economic development patterns under different premises in the form suitable for intuitive understanding.

The lower stratum of the model seeks a possibility of achieving the goals described by the upper stratum of the model by using a more precise description, and it suggests what kind of policies could be taken. There the guideline decided by the upper stratum of the model is built in the objective function for the lower stratum of the model. Demand supply relations based on the input-output table are considered, and the annual optimum investment plans are determined by using Quadratic Programming methods. Although the lower stratum of the model contains several elements analyzed by economics, it has been constructed especially for long-range planning and is not directed toward positivistic studies.

In developing this model, emphasis has been placed on the investigation of the real world; the Kinki area has been chosen as a study region. One reason for this choice is that most of the members participating in this project live in the Kinki area and are familiar with the situation there. Another reason is that the Kinki area is suffering from many problems and hence will provide us with realistic objects of research.

REGIONAL ALLOCATION MODEL

Outline of the Model

The model aims at a bold description of the regional status at the end of the planning period in relation to national development. The process to seek the future regional status is divided into four steps as shown in Figures 1a and 1b.

First Step: Assuming the growth rate of the national economy and population, compute the GNP, total population and accumulated social capital investment over the planning period. Set the macro structure of the Japanese economy at the end of the planning period freely and then estimate the final demand structure, the output from each industrial sector, the number of employed persons in each sector, water usage per unit product, and pollutant discharge per unit product. These turn out to be the inputs (exogenous variables) to the model described in the second step.

Second Step: Find the regional allocation of the industries and population under the constraints concerning the resources and the environment so as to share the social capital for population and production as equally as possible and to minimize the transportation demand. The result is obtained as a solution of a linear programming model.

Third Step: Compute the indices such as the regional land and water usage rates and the pollution level from the solution obtained in the second step. Output these indices with regional population, production output and social capital stock.

Fourth Step: Evaluate the output of the third step from the overall viewpoint. If the result is not preferable, return to the first step and change totally or modify the first hypothetical settings on the future economical structure.

Structure of the Linear Programming Model

The structure of the model is shown in Figure 2. Superscript i denotes the subregion to which the model's variable or parameter belongs. Variables with ○ express initial values at the first year of the planning period or fixed parameters. Constraints are indicated by ▷◁. Solutions of the model are given in ▭. A dependent variable which can be determined by other variables is denoted by □.

Industrial Sector

Industries are classified so that the changes in the production elements or parameters (for example, the number of employed persons, value added rate, input-output coefficient, etc.), the impact on the resources and environment (land, water usage per unit product, pollutant discharge per unit product, etc.), the change in the investment structure, consumption pattern, and the industrial structure can be taken into the model explicitly or implicitly.

Owing to the nature of the objective for this model, very detailed classification is not preferable. Therefore, it is kept at its minimum. Primary industries are put into one sector. Secondary industries are divided into three sectors (heavy and chemical, light manufacturing, and metal product and machinery). Tertiary industries are also put into one sector which includes construction industries. That is, all industries are classified into a total of five sectors, which is shown in Table 1.

The national product of each sector is given exogenously. Only three sectors of the secondary industries are the direct object of this model, and the model's regional allocation is decided by using linear programming. The allocations of the primary industries are given exogenously. Tertiary industries are allocated proportionally to the regional population. The reason for the exogenous allocation of primary industries is that a national policy that protects agriculture exists and it will not be easy to change its allocation very much in the future. Also, changing the regional allocation of agriculture freely is not desirable from the structure of the model itself, because agriculture has very large land and water usage per unit product and the diversion of these resources to other industrial regions has too much influence on the overall allocation.

The equations relevant to the regional allocation are given in the following:

primary: v_1^i given

secondary (2~4th sector): $\sum_i v_{2\sim4}^i = V_{2\sim4}$

tertiary: $v_5^i = V_5 P^i / P$

where

v^i: product of the i-th region;

V: national product;

P^i: population of the i-th region;

P: total population.

Population Sector

The total number of employed persons in each industrial sector is given exogenously. Primary and secondary people are allocated into each region proportionally to individual regional productions. Tertiary people are allocated to each region in proportion to the sum of the regional primary and secondary persons. These are written in equations as follows:

primary : $P^i_{w_1} = P_{w_1} v^i_1 / V_1$

secondary (2~4th sector): $P^i_{w_{2\sim4}} = P_{w_{2\sim4}} v^i_{2\sim4} / V_{2\sim4}$

tertiary : $P^i_{w_5} = P_{w_5} \left(\sum_{j=1}^{4} P^i_{w_j} \right) / \left(\sum_{j=1}^{4} P_{w_j} \right)$

where

P^i_w: employed persons of the i-th region;

P_w: total employed persons.

Regional population P^i is calculated by the next question by assuming the constant employment rate e.

$$\text{Population:} \quad P^i = \sum_{j=1}^{5} P^i_{w_j} / e \quad .$$

Constraints

As for the constraints, the resources (land and water), the environment, the social inertia accompanied by the reallocation of industries and population are taken into account. Although it is possible to imbed these constraints in the objective function described later, we prefer to use the constraints as they are, since it is possible to lead the solution (for example, the allocation pattern of the industries and population) in the desirable direction by just strengthening or weakening any of these constraints.

Water Resource

The upper bound of the regional water supply is set at 60%

of the runoff from woodland. Regional water usage is calculated for the allocated population and industries by using the usage per unit population or product. Therefore,

$$\text{water:}\quad w_p P^i + \sum_{j=1}^{5} w_j v_j^i \leq W^i \quad ,$$

where

w : water usage per unit product;

W^i: upper bound for the water supply for the i-th region.

Land Resource

The upper bound for the regional usable land is set at the regional inhabitable land, which excludes the land for agricultural use.

$$\text{land:}\quad \ell_p P^i + \sum_{j=1}^{5} \ell_j v_j^i \leq L^i \quad ,$$

where

ℓ : land usage per capita or per unit product;

L^i: inhabitable land of the i-th region (excluding agricultural land).

Environment

For air pollution, SO_x and NO_x are considered; only BOD is considered for water pollution. CO, solid wastes, and other pollutants should be taken into account; however, we excluded them because of the lack of data and the uncertainty of the discharging rate for these pollutants.

$$SO_x:\quad \sum_{j=2}^{5} s_j v_j^i \leq S^i$$

$$NO_x:\quad \sum_{j=2}^{5} n_j v_j^i \leq N^i$$

$$\text{BOD:}\quad b_p P^i + \sum_{j=2}^{5} b_j v_j^i \leq B^i \quad ,$$

where

s,n,b : pollutant discharge per capita or per unit product;

S^i,N^i,B^i: total allowable amount of pollutant.

Reallocation of Population and Industries:

These constraints have been adopted in order to maintain the reality of the model to some extent. That is, these constraints inhibit the extreme change from the present allocation patterns.

Population : $a_\ell^i P_o^i \le P^i \le a_h^i P_o^i$

Heavy and chemical : $a_{2\ell}^i v_{2,o}^i \le v_2^i \le a_{2h}^i v_{2,o}^i$

Light manufacturing : $a_{3\ell}^i v_{3,o}^i \le v_3^i$

Metal product and machinery: $a_{4\ell}^i v_{4,o}^i \le v_4^i$,

where

a^i: multiplication factor;

v_o^i: initial value of the product in the i-th region.

Objective Function

The objective function considered here intends to minimize the demand for transportation that is necessary to fill the regional supply-demand gaps and to make the social capital stock per capita and per unit product uniform.

Transportation

We assume a hypothetical transportation demand for the m-th goods produced in the i-th region. That is, the export, the import in the i-th region, and the transportation from the i-th region to the k-th region are taken into account. The costs associated with transportation are determined by considering the distances among regions and the kind of goods. Total transportation cost is taken as the objective function, that is:

$$J_1 = \sum_{mik}\sum\sum T_m^{ik} Y_m^{ik} + \sum_{mi}\sum T_m^i Y_m^i$$

where

Y_m^{ik}: transportation of the m-th goods from the i-th region to the k-th region;

Y_m^i: export and import in the i-th region;

T_m^{ik}: transportation cost per unit;

T_m^i: transportation cost per unit;

and the following constraints hold for the variables:

$$\sum_k Y_m^{ik} + \delta_m Y_m^i = X_m^i$$

$$\sum_i Y_m^{ik} + (1-\delta_m) Y_m^i = (AX^i)_m + (F_d^k)_m$$

$$\delta_m = \begin{cases} 1 & \sum_i X_m^i \geq \sum_i \left\{ (AX^i)_m + (F_d^i)_m \right\} , \\ 0 & \text{or else} \end{cases}$$

where

A: input coefficient matrix;

AX^i: intermediate demand of the i-th region

$$X^i = \begin{bmatrix} x_1^i \\ x_2^i \\ \cdot \\ \cdot \\ x_5^i \end{bmatrix} = \begin{bmatrix} k_{v_1}^{-1} \cdot v_1^i \\ k_{v_2}^{-1} \cdot v_2^i \\ \cdot \\ \cdot \\ k_{v_5}^{-1} \cdot v_5^i \end{bmatrix} ;$$

X^i: output of the i-th region;

k_v: value added rate.

F_d^i denotes the final demand of the i-th region which is calculated by using the following equation:

$$F_d^i = B_p K_p V^i + B_{gn} K_{gn} V^i + B_{ge} K_{ge} VP^i/P$$

$$+ B_{cp} K_{cp} VP^i/P + B_{cg} K_{cg} VP^i/P \quad ,$$

where

K_p: private capital investment rate;

K_{gn}: economic overhead capital investment rate;

K_{ge}: social overhead capital investment rate;

K_{cp}: private consumption expenditure rate;

K_{cg}: government consumption expenditure rate;

B: investment or consumption vector.

The excess demand of the i-th region, D^i, is defined as follows:

$$D^i = X^i + AX^i - F_d^i \quad .$$

Social Capital

The economic overhead capital is

$$J_2 = \sum_i \mid Z_n^i - \bar{Z}_n^i \mid \quad ,$$

where

Z_n: capital stock at the final year;

$\bar{Z}_n$: standard for the stock.

The following constraints hold for Z_n^i:

$$Z_n^i = k_{no}^i + k_n^i$$

$$K_n = \sum_i k_n^i$$

$$\delta_n^- K_n V^i/V \leq k_n^i \leq \delta_n^+ K_n V^i/V \quad ,$$

where

k_n^i: accumulated capital investment to the i-th region;

k_{no}^i: initial value of the capital stock;

K_n: total accumulated capital investment;

δ_n: multiplication factor.

The social overhead capital is

$$J_3 = \sum_i \mid z_\ell^i - \bar{z}_\ell^i \mid \quad .$$

The definitions of the variables and the constraints are similar to those for the economic overhead capital.

In order to integrate these individual objective functions into one, we take a weighted some of them. That is:

$$J = W_1 J_1 + W_2 J_2 + W_3 J_3$$

where W_1, W_2, W_3 can be parametrically given.

APPLICATION TO THE KINKI REGION

The Planning Period is Chosen to be 30 Years

Since the Kinki region is extremely complicated topographically, it is desirable to divide it into several subregions of similar geographic and socio-economic features. However, at the present stage, we have no available data other than the prefecture base. Therefore, we divide the Kinki region into seven subregions by the prefecture base. The outer region of Japan is divided into six subregions by considering interregional relationships. These are summarized in Figure 3.

The results of two case studies are shown below. Case 1 is considered the most probable future growth pattern of the Japanese economy. On the other hand, Case 2 seems to be close to the upper bound of the growth pattern where the constraints on the resources and environment become more severe.

Case 1

Growth Rate

GNP: 5.0%/year;

Population: 0.8%/year.

Assumed Macro Frame at the Final Year

Final demand component ratio:

- private capital investment rate, K_p 13.5%
- social overhead capital investment rate, K_{ge} 15.5%
- economic overhead capital investment rate, K_{gn} 7.0%
- private expenditure rate, K_{cp} 52.0%
- government expenditure rate, K_{cg} 12.0%

Consumer expenditure income patterns:

- similar to those of the USA at present.

National products by industrial sectors, V_j (in 10 billion yen):

Sector j	1	2	3	4	5
V_j	784	3151	2497	5319	19,741

Regional productions by primary industries, v_1^i (in 10 billion yen):

Region i	1	2	3	4	5	6	7
v_1^i	275.9	111.7	99.1	5.8	6.7	6.1	3.5

8	9	10	11	12	13
17.5	7.5	11.2	64.9	42.7	126.0

Employed persons by industrial sectors, P_{w_j} (in thousands):

Sector j	1	2	3	4	5
P_{w_j}	3407	4908	6137	9890	37,597

Employment rate, e: 47%.

Land and water usage per unit product:

- Half of the present usage, which is shown in Figure 4.

Land and water usage per capita:

- Land : $100m^2$;
- Water: $62m^3$/year.

Pollutant discharge per unit product:

- SO_x: 95% cut down of the present discharge rate;
- NO_x: 90%;
- BOD: 95%

(Present discharge rates are shown in Figure 5);

BOD discharge per capita: 12 kg/year.

Fixed Parameters

- Ultimate land supply = inhabitable land area (see Figure 6);
- Ultimate water supply = 60% of runoff from woodland (see Figure 7).

Other parameters are derived from the following sources:

- The Government of Japan (1974), "1970 Input-Output Table";
- Economic Planning Agency (1975), "Annual Report on National Income Statistics".

Initial Values

Data Sources are shown here.

Industrial products by regions and sectors:

- Primary and tertiary: Economic Planning Agency (1975), "Profectural Income Statistics";
- Secondary: Ministry of International Trade and Industry (1972), "1970 Census of Manufactures".

Regional population: Office of the Prime Minister (1972), "Japan Statistical Yearbook".

Social capital stock: Mitsubishi Integrated Research Laboratory (no date); "National Land Use Planning and Regional Economy".

Optimum Solution

The optimum solution obtained by using this model is summarized in Figures 8 to 11. The necessary changes of allocation pattern from the present to the final year are shown in terms of the mean annual growth rate. In Figures 10 and 11 the usage rate of land and water, and the pollution level at the final year, are shown in percentages.

It is clear that the Osaka prefecture is subject to the most severe conditions of land, water, and environmental pollution. Osaka is seen to have no alternative of keeping the growth rate of both GRP and population lower. The Kanto region has a lower growth rate in comparison to other regions of Japan. This low growth appears to depend on the scarcity of water resources in this region.

Case 2

Growth Rate

GNP: 7.0%/year;

Population: 0.8%/year.

Assumed Macro Frame at the Final Year

Final demand component ratio:

- private capital investment rate, K_p 17%
- social overhead capital investment rate, K_{ge} 13%

- economic overhead capital investment rate, K_{gn} 8%
- private expenditure rate, K_{cp} 52%
- government expenditure rate, K_{cg} 10%

Consumer expenditure income patterns:

- Same as Case 1.

National products by industrial sectors, V_j (in 10 billion yen):

Sector j	1	2	3	4	5
V_j	184	5558	4374	10,096	34,630

Employed persons by industrial sectors, P_{w_j} (in thousands):

Sector j	1	2	3	4	5
P_{w_j}	3407	4814	5960	10,409	37,349

Other parameters are the same as for Case 1.

Optimum Solution

The optimum solution is summarized in Figures 12 to 15. The Osaka prefecture is asked for a more drastic change in its industrial structure. The heavy and chemical industry and the light manufacturing industry, all of which need larger amounts of land and water and have higher pollutant discharge rates, are almost completely depressed (zero growth). In order to achieve a 7% annual growth rate of GRP per capita, the population needs to stay at the present level.

FINE DYNAMIC MODEL

Outline of the Model

The objective of this model is to find the annual scheme for achieving a goal determined by using the preceding model. Through this process, it is also expected to confirm the dynamic feasibility of the goal. The structure of the model is shown in Figure 16.

The regional products of each industrial sector are obtained by using the Cobb-Douglas production function. GRP is obtained by integrating these products. Part of this GRP is assigned to investments and the rest to consumption. The production of the next year will be changed according to this assignment. If this is done skillfully, the optimum assignment will be achieved. This is executed in the evaluation block. Once the assignment is determined, the demands including the intermediate one are also determined under the moderate assumption.

The transportation necessary to fill the supply-demand gaps is obtained by solving the transportation problem, which is shown in the transportation block. The simplex multiplier obtained in the solution process indicates the variation of transportation demand due to the change of production. This multiplier is also used in the evaluation block.

All blocks other than the evaluation and the transportation block are simulation blocks.

Precise Description of the Model

Simulation Block

A more detailed description is shown in Figure 17.

Products: Let the investment to the j-th industrial sector in the i-th region be J_{pij} and let the capital stock and labor force of the present year be K_{ij} and L_{ij}, respectively. Then the product of value added V_{ij} is obtained by using the following Cobb-Douglas production function:

$$V_{ij} = A(K_{ij})^{\alpha_j}(L_{ij})^{\beta_j}e^{\gamma_j t} \quad .$$

The corresponding outputs are calculated as

$$X_{ij} = R_{kvj}V_{ij}$$

where R_{kvj} = reciprocal of value added rate of the j-th sector.

Employed Persons: In order to determine the employed persons, we put the following assumptions:

- The age structure of the population is the same in all regions and this also holds when immigration exists;
- The employment rate by age is the same in all regions;
- Osaka, Hyogo, Nara, Kyoto and Shiga prefecture constitute a single commuting area, which is treated as one region in the determination of employed persons;
- The total employed persons depend only on the population by age and on the employment rate by age.

Under these assumptions, the employed persons are determined as follows. Denoting the number of persons of the i-th region employed next year as L_i^*, the residential population as P_i^*, and the employment rate as α_L, the following equation holds:

$$L_i^* = \alpha_L P_i^* \quad .$$

The next year's labor force is determined by

$$L_{ij}^* = (L_{ij} + \frac{L_{ij}}{K_{ij}} \cdot I_{pij}) \frac{L_i^*}{\sum_j (L_{ij} + \frac{L_{ij}}{K_{ij}} I_{pij})} \quad .$$

Capital Stock: Gross capital stock is assumed to decrease with a constant depreciation rate δ_k. The next year's gross capital stock of the j-th sector becomes

$$K_{ij}^* = K_{ij}(1 - \alpha_k) + I_{pij} \quad .$$

Social capital stock is treated in a similar manner. The social overhead capital stock is denoted as K_{gli} and the economic overhead capital stock as K_{gni}.

Demand: The regional final demands are obtained by using the following equation:

$$F_d = B_p I_p + B_{gn} I_{gn} + B_{g\ell} I_{g\ell} + C + C_{res} + C_g$$

where

B: investment matrix;

C: private consumption expenditure;

C_g: government consumption expenditure;

C_{res}: consumption outside household.

The private consumption expenditure of the i-th region is calculated by using the consumption rate γ_{cp} as

$$C_i = GNP \cdot \gamma_{cp} \cdot \frac{P_i}{\Sigma P_i} \cdot C^o \quad ,$$

where C^o is the consumption vector and the column sum of its elements is equal to 1. C^o is obtained from the equation as

$$C^o = GC_p \quad ,$$

where

C_p: consumption by commodities;

G: conversion matrix.

The government consumption expenditure is calculated by using the equation

$$C_{gi} = GRP_i \cdot \gamma_{cg} \cdot C_g^o \quad ,$$

where

γ_{cg}: government consumption rate;

C_g^o: government consumption vector.

Consumption outside households is obtained from the input-output table.

The intermediate demand is obtained by using the output X input-output table A as Ax. The table is assumed to be the same for all regions. Where the allocation of industries changes widely, the input from the transportation sector is likely to change, but this effect is neglected here.

As a result, the regional demands are obtained as follows:

$$D - AX + F_d \quad .$$

Once the demand and supply are determined, the export and import are also determined immediately. That is the export and import denoted as Xe - M is

$$Xe - M = (E - A)X - F_d \quad .$$

Transportation Block

The transportation problem is formulated as follows:

$$J = \sum_{i,k,j} T^j_{ik} Y^j_{ik}$$

where

Y^j_{ik}: transportation of the j-th goods from the i-th region to the k-th region;

T^j_{ik}: transportation cost.

And the constraints are

$$\sum_k Y^j_{ik} + \delta^j Y^j_{i,n+1} = S^j_i \quad , \quad i = 1 \sim n, \; j = 1 \sim m$$

$$\sum_i Y^j_{ik} + (1 - \delta^j) Y^j_{n+1,k} = D^j_k, \; k = 1 \sim n, \; j = 1 \sim m$$

$$\delta^j = \begin{cases} 1 & \sum_i S^j_i \geq \sum_i D^j_i \\ 0 & \text{or else} \end{cases}$$

where

S: regional supply;

D: regional demand.

This transportation problem can be solved by using linear programming methods. The minimum value of J can be interpreted as the least necessary transportation demand. The simplex multiplier π obtained in the solution process indicates how the transportation demand will be changed following the variation of S and D. π is fed back into the evaluation block.

Evaluation Block

In the evaluation block one step optimization is performed. The scheme is as follows. First we start from an investment allocation pattern arbitrarily chosen. Then the state of the next year is predicted by executing the simulation block of the model. At the same time the value of the objective function is calculated. The initial allocation pattern can be adjusted incrementally by noting the variation of the objective function. The quadratic form is adopted for the objective function and the constraints are chosen to be linear. Thus, the optimum solution is determined by using the quadratic programming method.

Objective Function: The terms considered in the objective function are as follows:

- Population: uniforming of the population density.

$$x_i = Pi + \Delta Pi \qquad (i = 1 \sim 13)$$

$$J = \underline{x}^t \underline{Qx}$$

where

$\underline{Q}$: diagonal matrix with elements of $1/S^i$;

S^i: inhabitable land area of the i-th region.

Resistance to demographic change is

$$x_i = \Delta Pi$$

$$J = \underline{x}^t \underline{Qx}$$

where

$\underline{Q}$: diagonal matrix with elements of $1/P^i$;

P^i: resident population of the i-th region.

- Labor: reduction of the supply-demand gap of the labor force.
- Capital Stock: uniforming of the social overhead capital; uniforming of the transportation production per unit economic overhead capital.
- Production: uniforming of the production per unit land area and per capita; reduction of the supply-demand gap; improvement of the productivity.

$$J = \sum_{ij}\sum (V_{ij}{}^{k} - \gamma_{ij}V_{ij})^2$$

where γ_{ij}: annual growth rate specified beforehand.

- Transportation: minimization of the transportation demand.
- Natural environment and crude oil demand: reduction of the water, land and crude oil usage.
- Others: regulation of private and government investment.

The overall objective function is composed of the weighted sum of the individual terms. As for the constraints, the meanings are clear. Therefore, all of the detailed equations are omitted here.

Inequality and Equality Constraints: The terms considered are as follows:

- water,
- land,
- crude oil,
- investment rate,
- consumption rate,
- GNP,
- population movement.

Application

This fine dynamic model is used to achieve the goal selected by using the regional allocation model; the exponential growth is chosen as a guideline. The principal difference from the allocation model is in the sectoral division. In the dynamic model, industry is divided into nine sectors whose classifications are shown in Table 1.

For Case 1 shown above, that is, the 5% annual growth case, the dynamic feasibility is confirmed almost completely. The results are shown in Figures 18 to 23.

For Case 2, that is, the 7% growth case, the feasibility is only partly confirmed. The growth rate declines gradually as the time approaches the final year of the planning period. This is caused mainly by the shortage of water. The results are shown in Figure 24.

CONCLUSION

This paper has dealt with the model developed for long-range regional planning and its application to the Kinki area. The hierarchical approach using two types of models, a coarse regional allocation model and a fine dynamic model, is shown to be useful for very long-range planning. The research is still under way and the author is trying to improve the model and the data further.

ACKNOWLEDGMENT

This research is partly supported by the Japan Computer Usage Development Institute. The dynamic model was originally developed by Professor Kaya of the University of Tokyo and his collaborators. The authors express their sincere thanks to them.

Table 1. Industrial sectors.

Name of sector: 5 sectors	Name of sector: 9 sectors	Industry
I. Primary	1 Agriculture, forestry and fisheries	Agriculture Forestry Fisheries
	9 Mining	Mining
II. Second-ary-1	2 Heavy and chemical	Pulp, paper and paper prod-ucts Chemicals Petroleum and coal products Nonmetallic mineral products Iron and steel Nonferrous metal products
III. Second-ary-2	3 Light manufacturing	Food and beverages Textile and apparel products Lumber and wood products Furniture and fixtures Printing and publishing Leather and leather products Rubber products Miscellaneous manufacturing
IV. Second-ary-3	4 Metal and machinery	Fabricated metal products Ordinary machinery Electrical machinery Transport machinery Precision machinery
	5 Energy	Electricity, gas, and water
V. Tertiary	6 Services	Commerce and finance Insurance and real estate Services Public service Others
	7 Construction	Construction
	8 Transportation	Transportation Communication

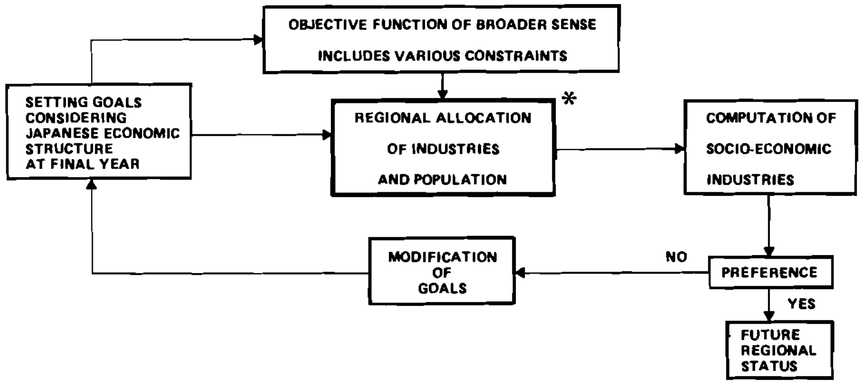


Figure 1a. Steps in describing future regional status in relation to national development.

---

*Detailed structure of this block is shown in Figure 1b.

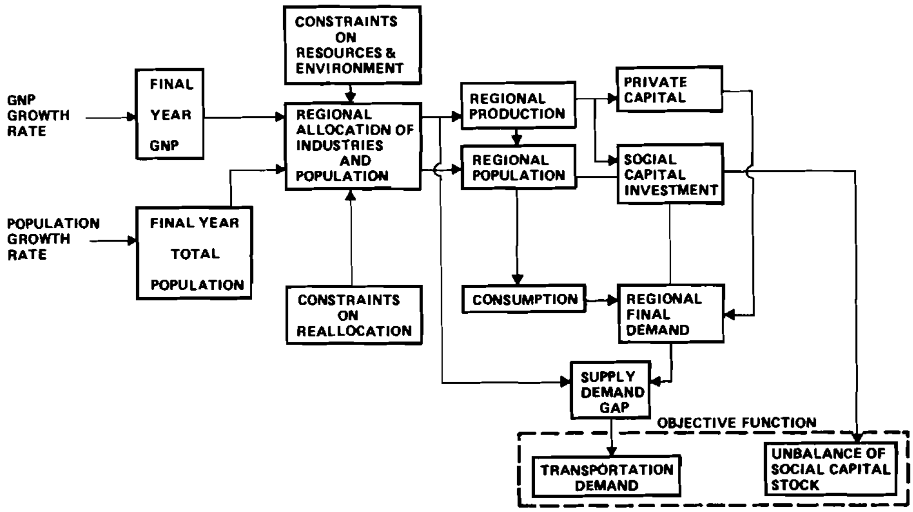


Figure 1b. Steps in determining the regional allocation of industries and population.

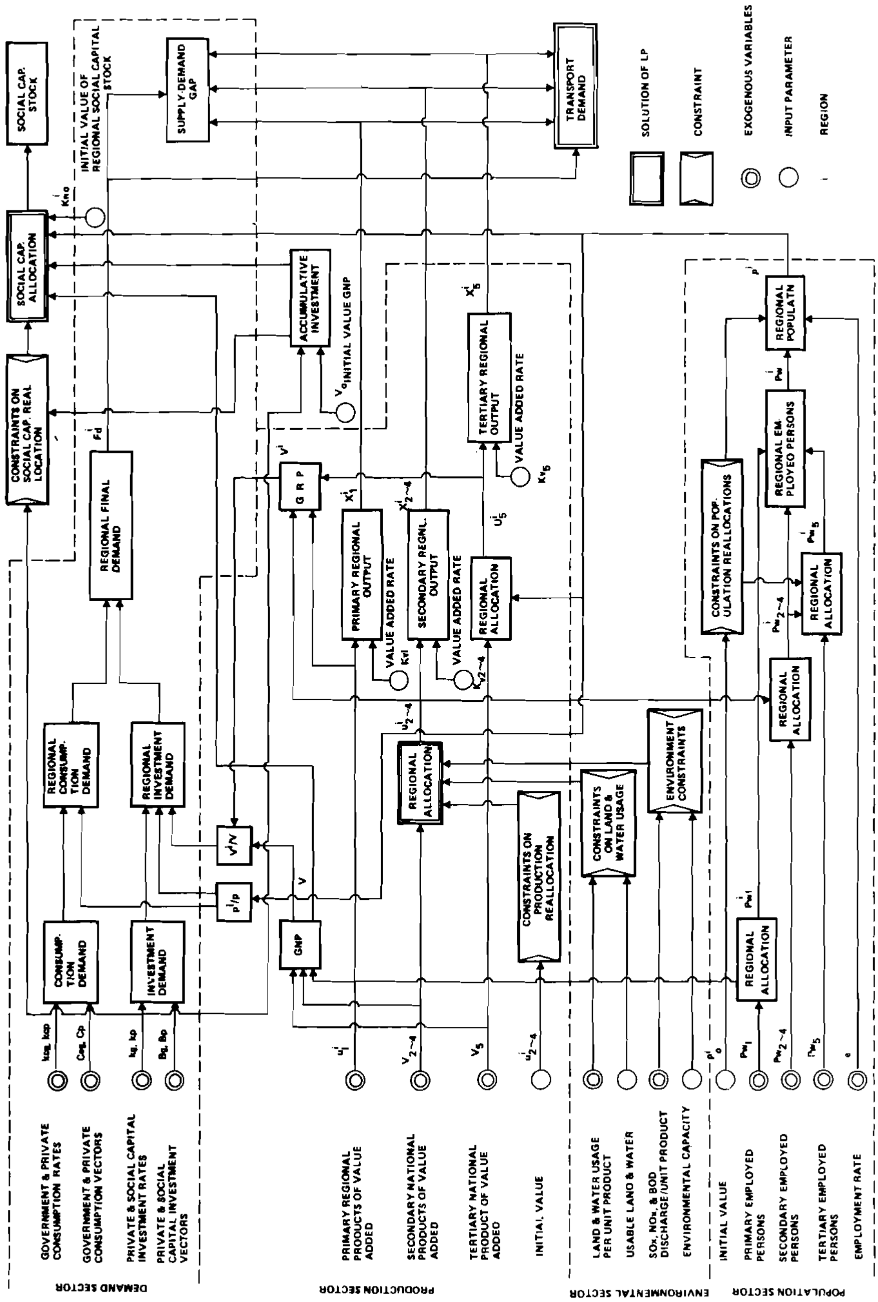


Figure 2. Regional allocation model.

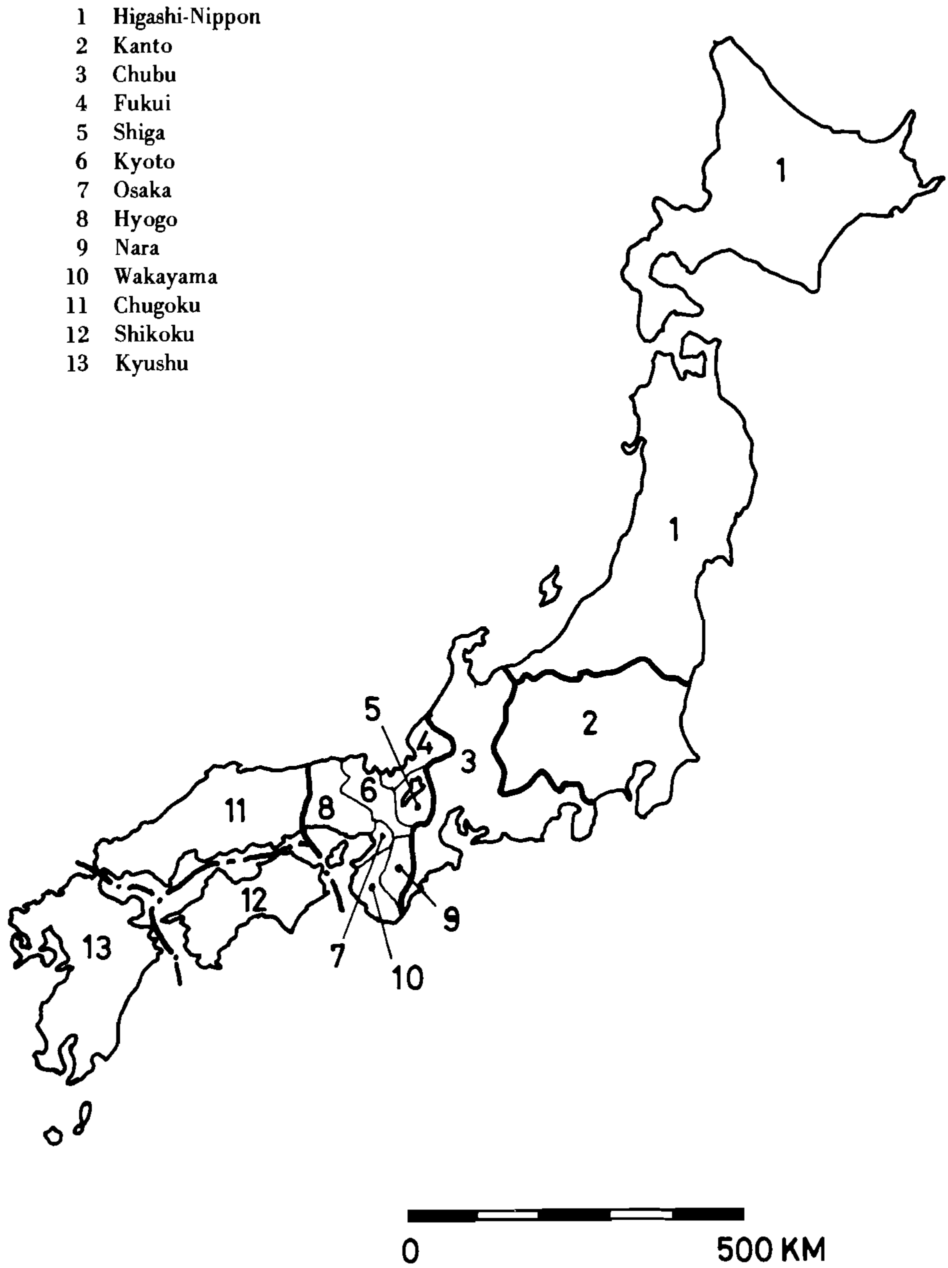


Figure 3. Regional divisions in Japan.

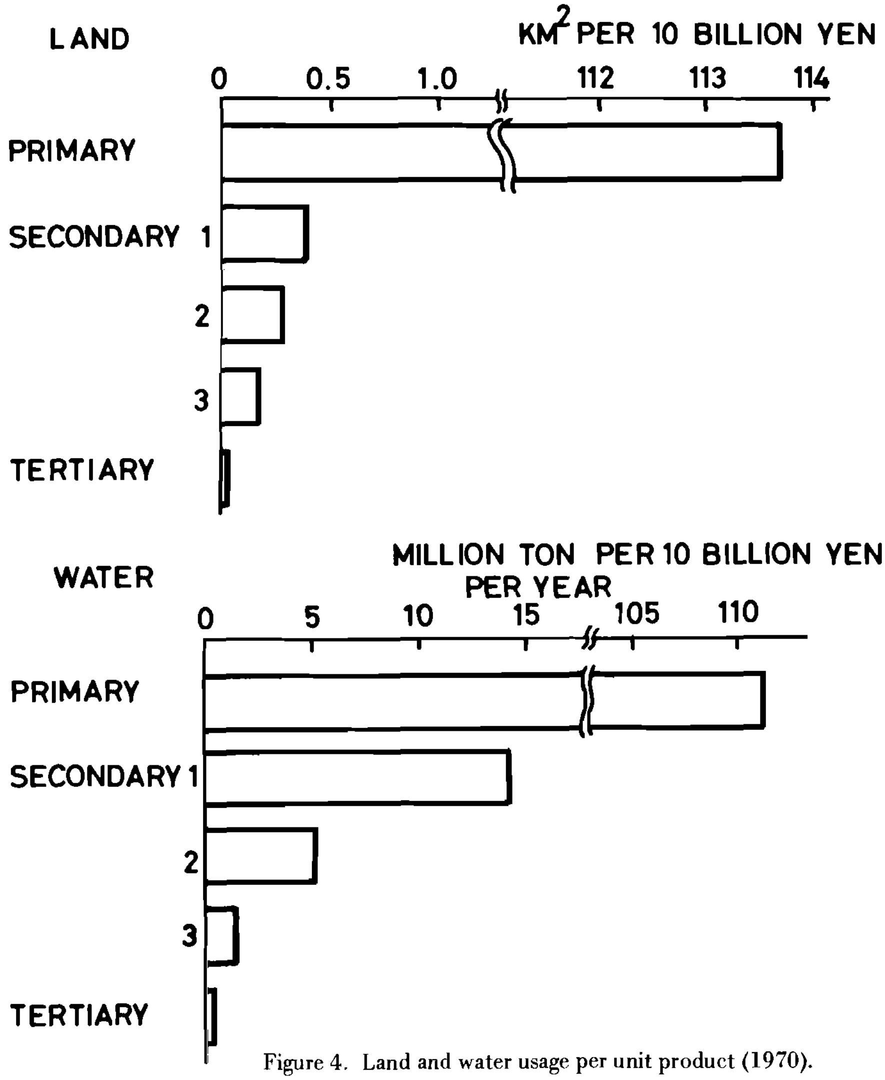


Figure 4. Land and water usage per unit product (1970).

Sources: Ministry of International Trade and Industry (1972), "1970 Census of Manufactures".
Ministry of Agriculture and Forestry (1974), "Statistical Yearbook on Agriculture, Forestry and Fishery".
Ministry of Construction (1973), "The Second Report on Water Utilization Survey in Great Spaces".

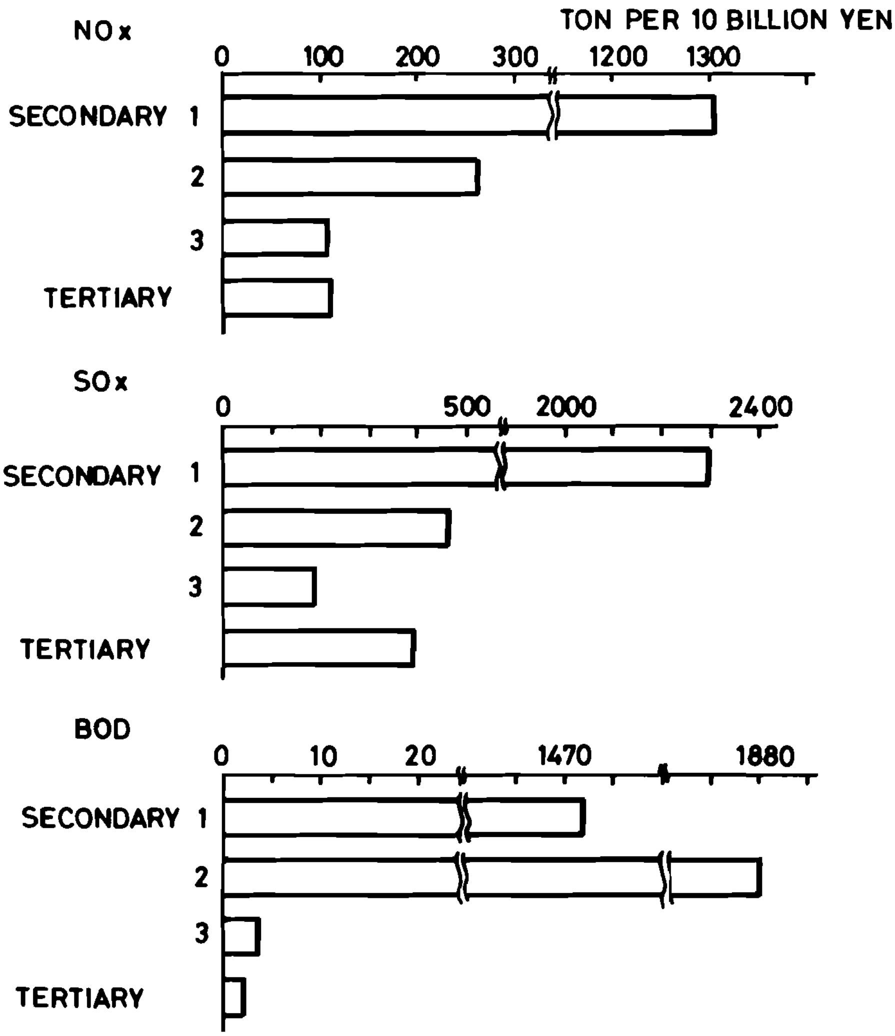


Figure 5. Pollutant discharge per unit product (1970).

Sources. SO_x, NO_x.: Institute of Japan Energy Economic Research (1972), "Energy Matrix".

BOD. Estimates by Environmental Protection Agency.

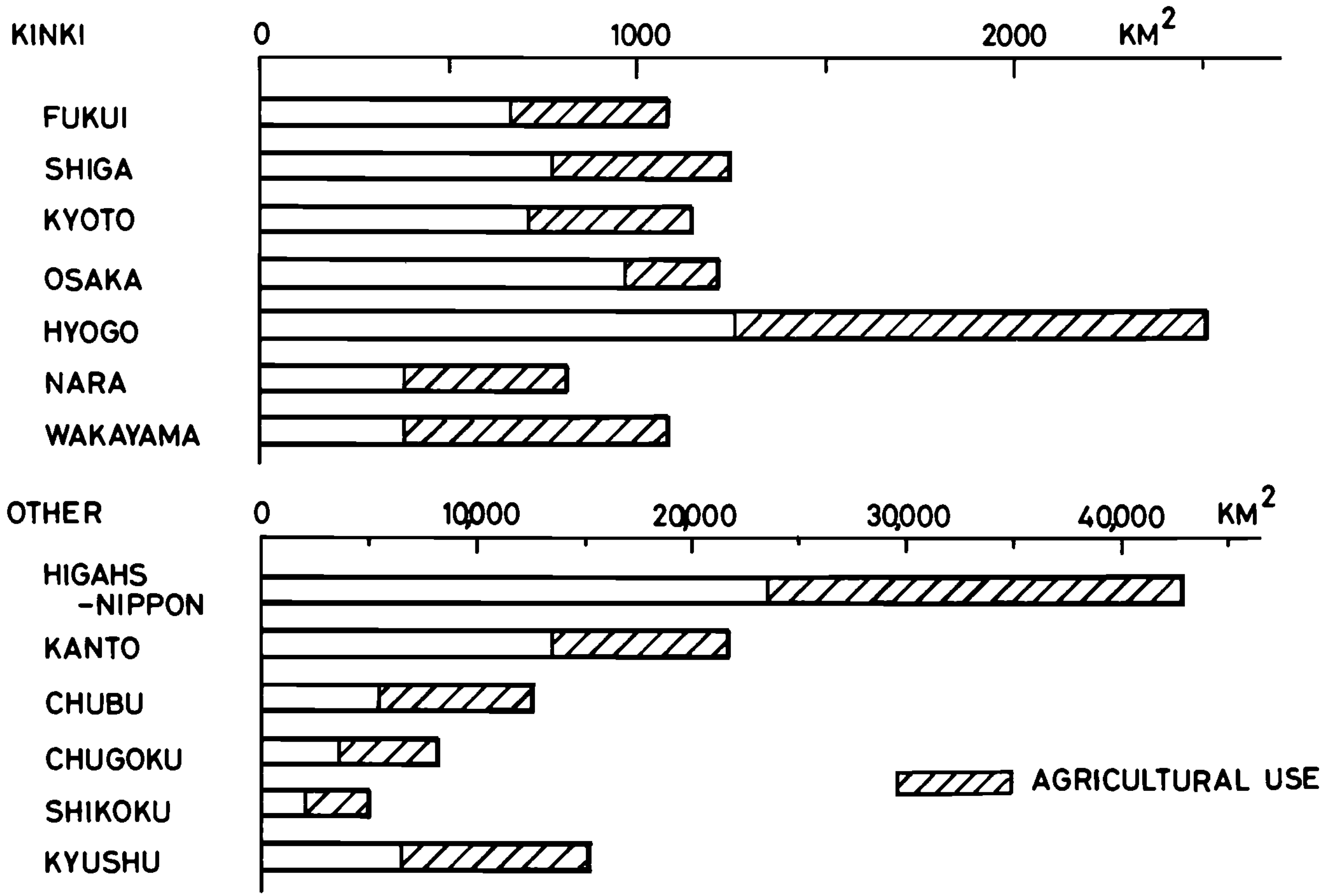


Figure 6. Inhabitable land area = total area - (forests + grassland + lakes and marshes).

Source: Office of the Prime Minister (1972), "Japan Statistical Yearbook".

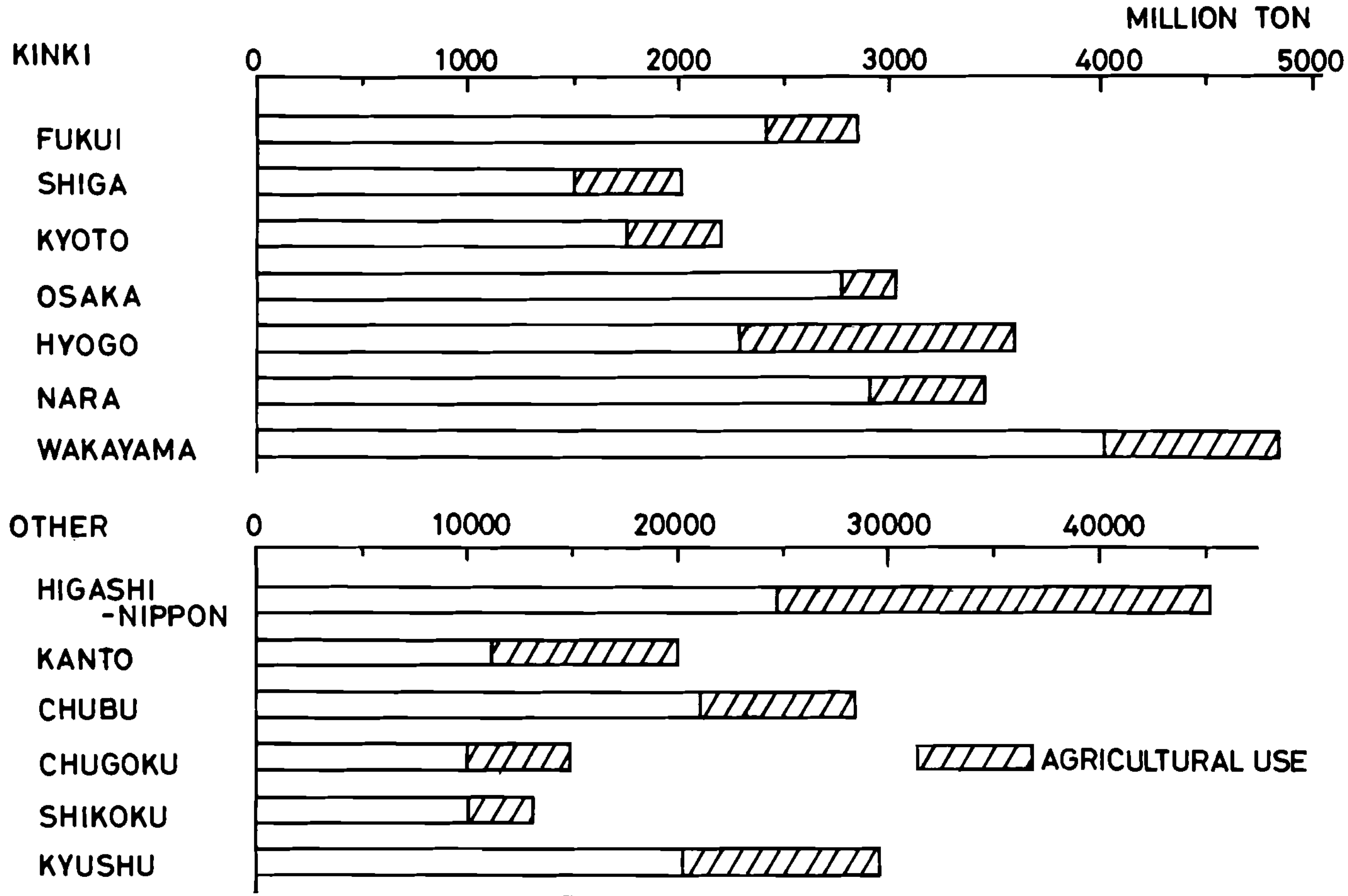


Figure 7. Water resources.

Sources: Institute of Hydrology, "1974 Annual Report on Water Economy".

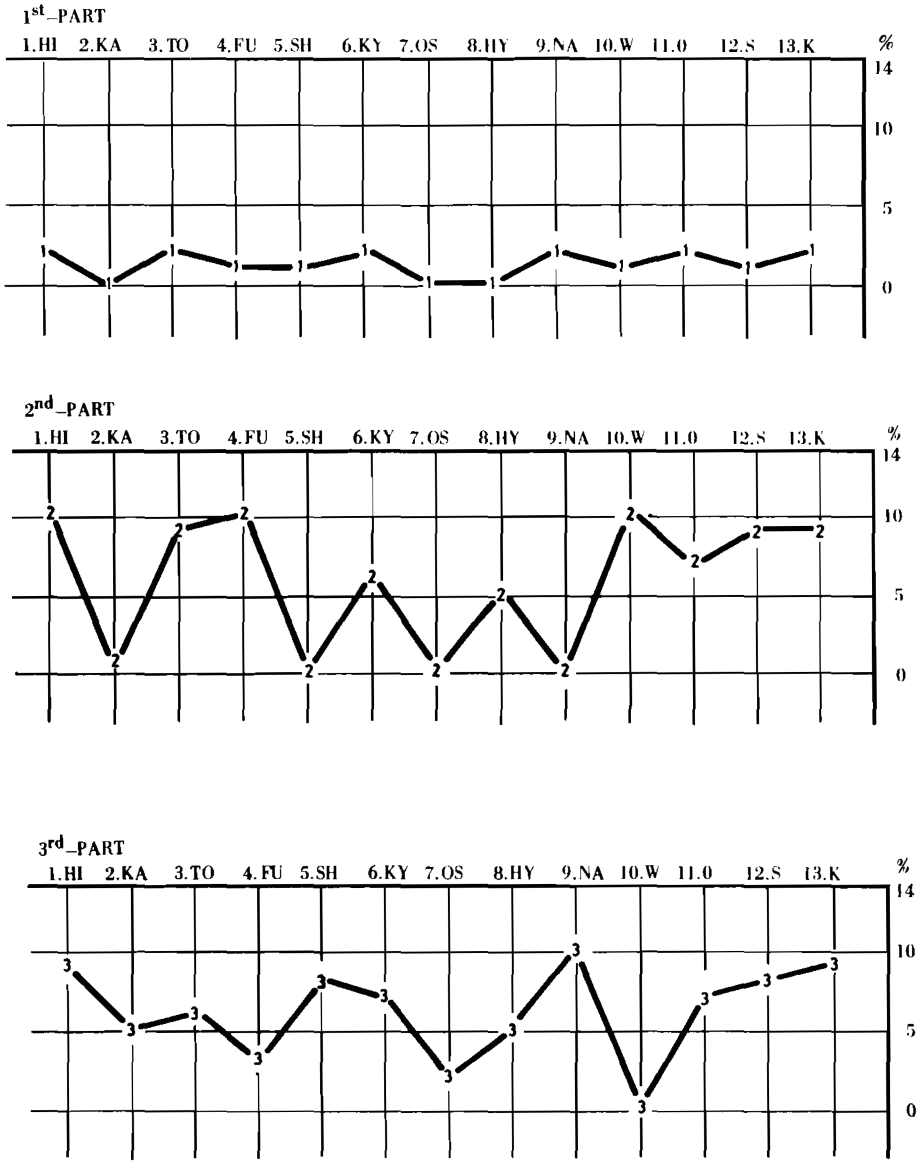


Figure 8. Growth rate of regional production (Case 1).

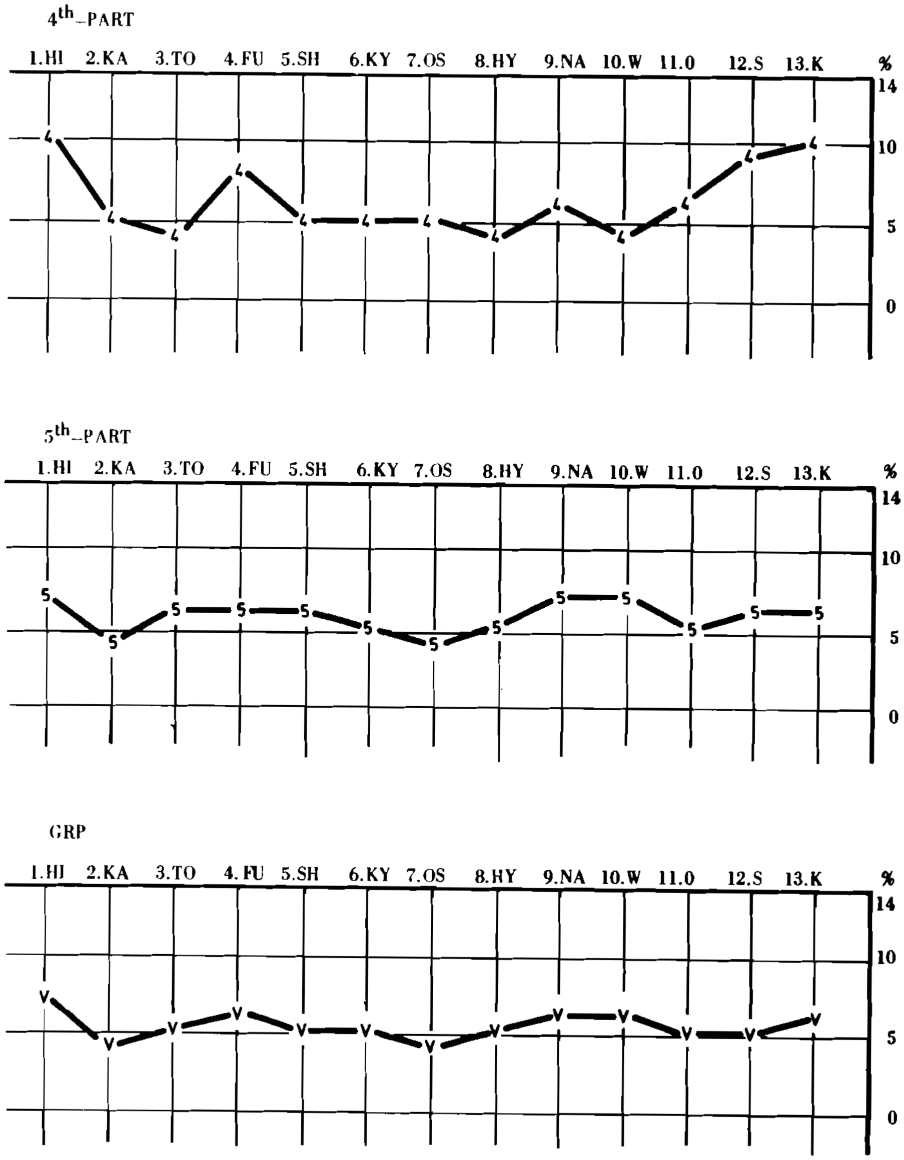


Figure 8. (continued).

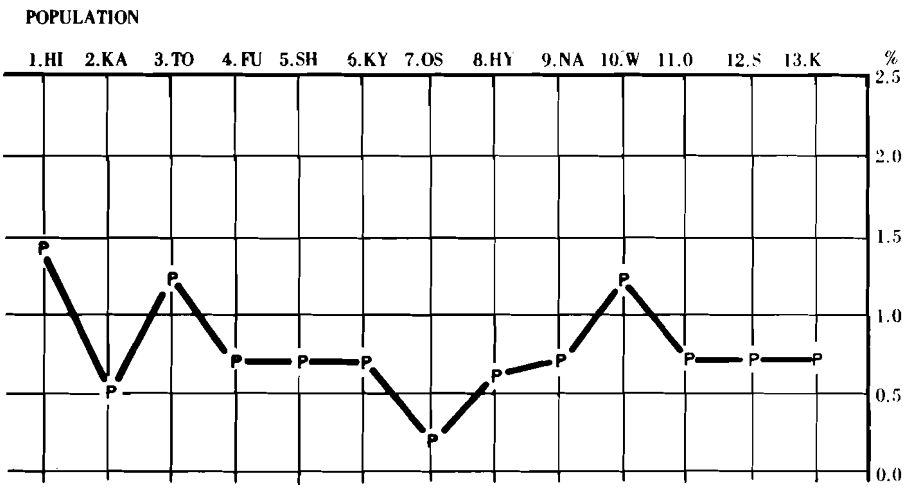


Figure 9. Growth rate of regional population (Case 1).

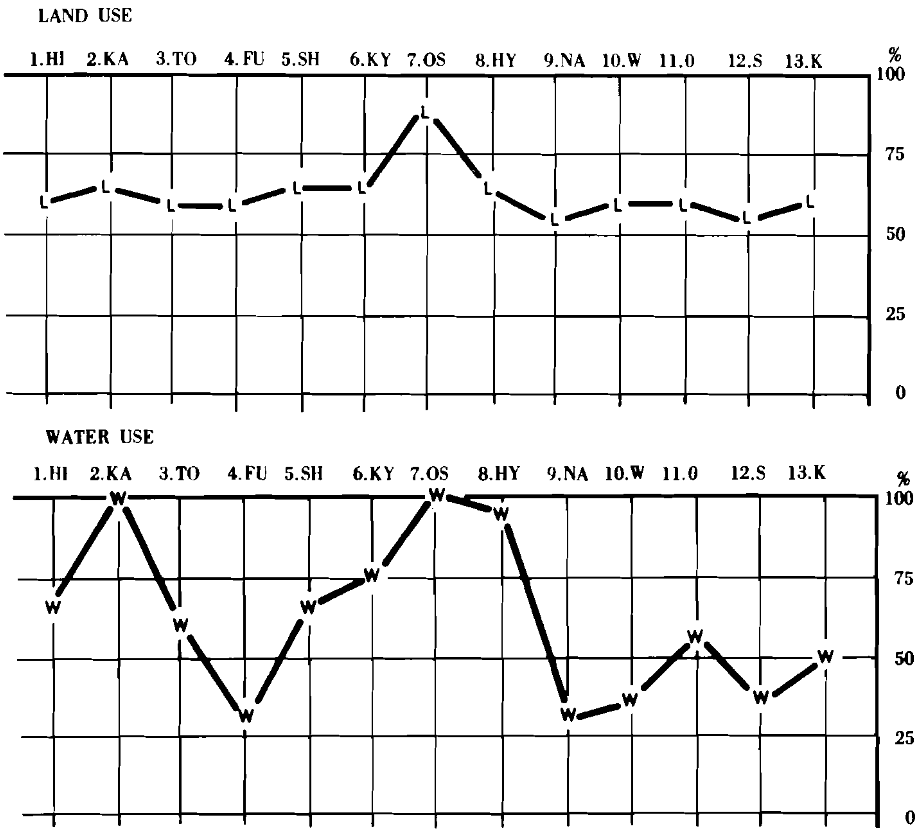


Figure 10. Land and water usage rate (Case 1).

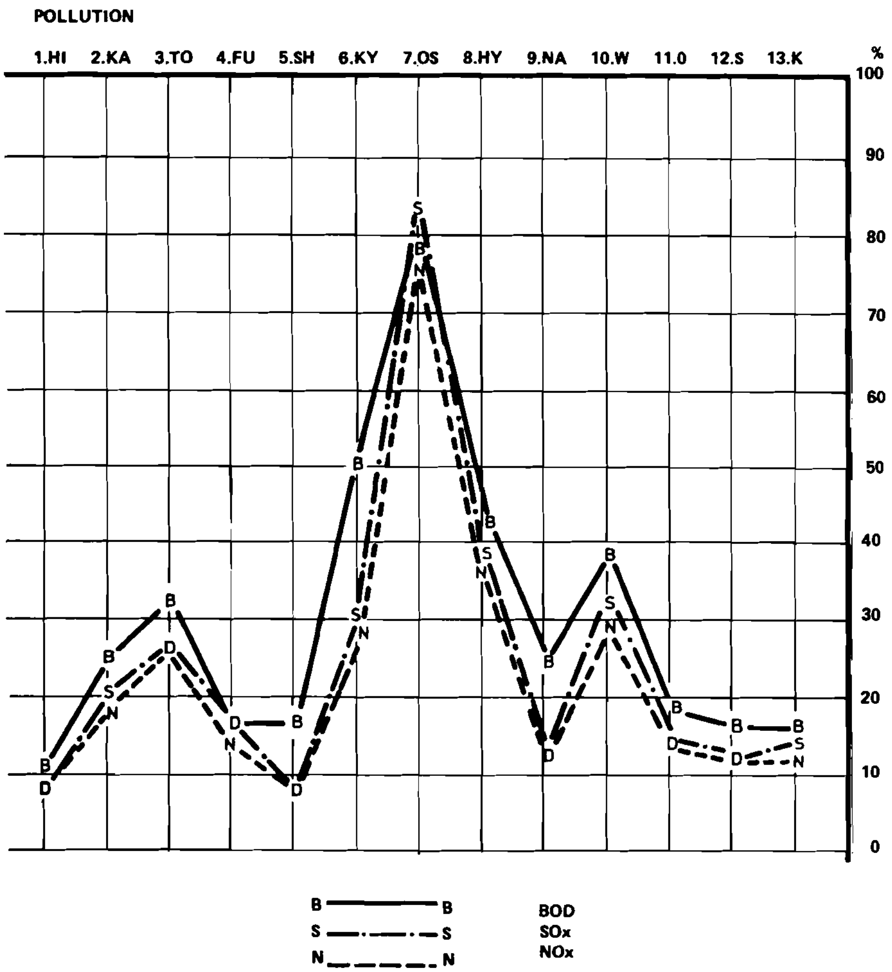


Figure 11. Pollution level (Case 1).

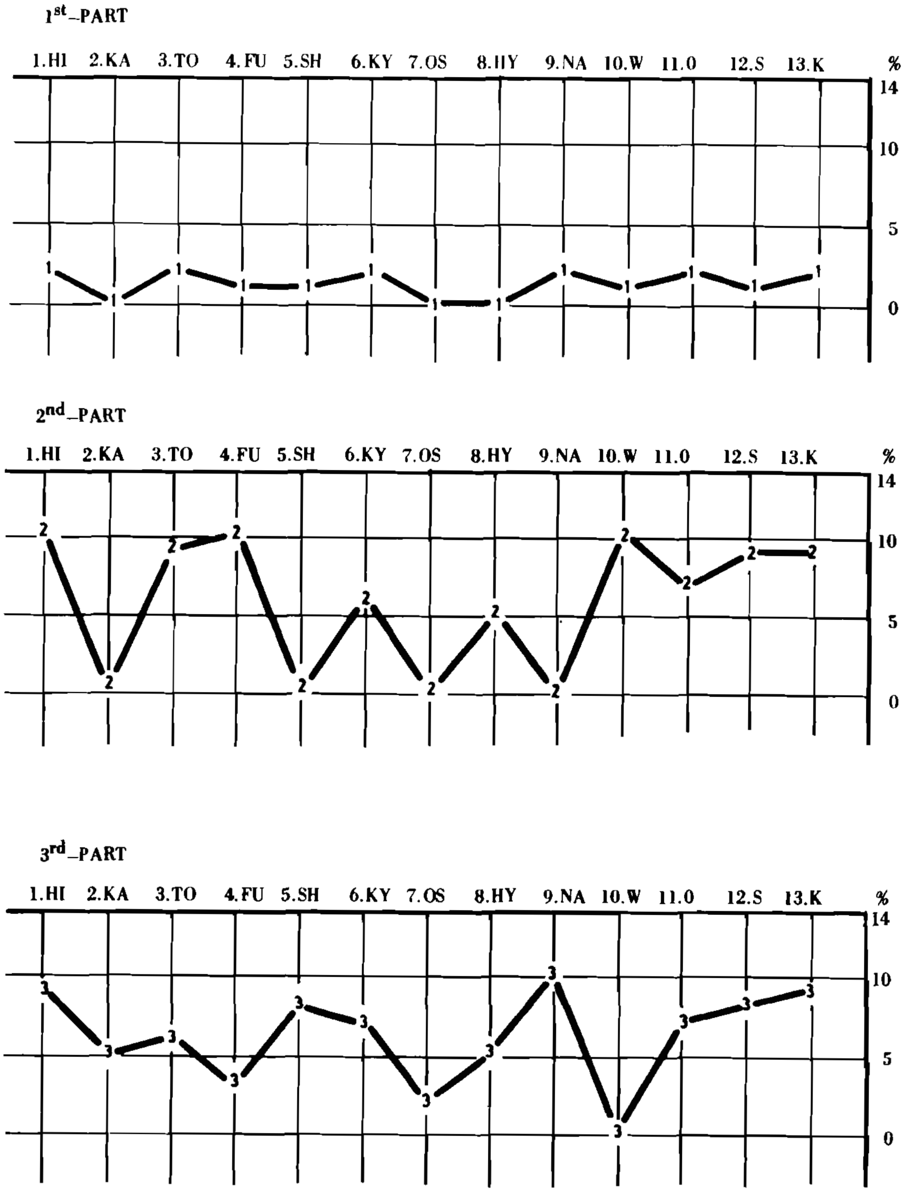


Figure 12. Growth rate of regional production (Case 2).

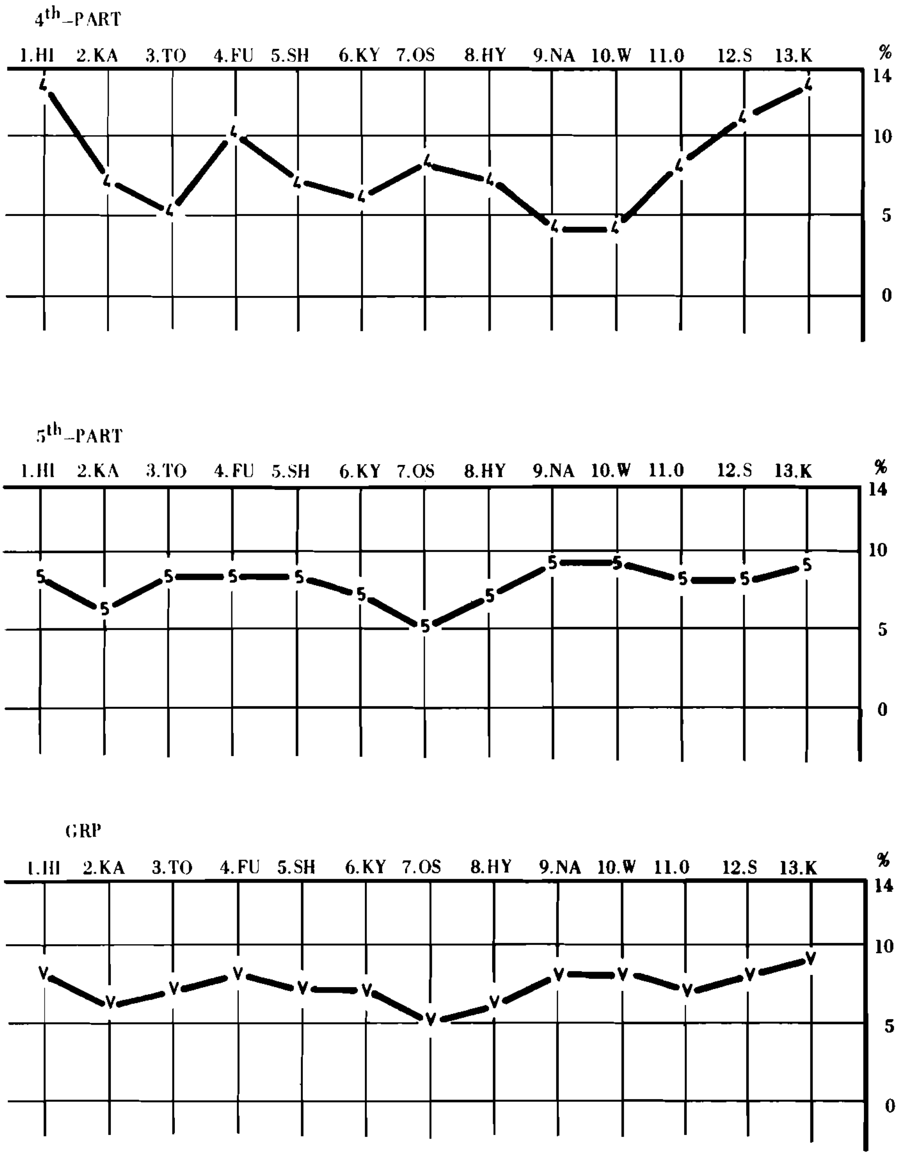


Figure 12. (continued).

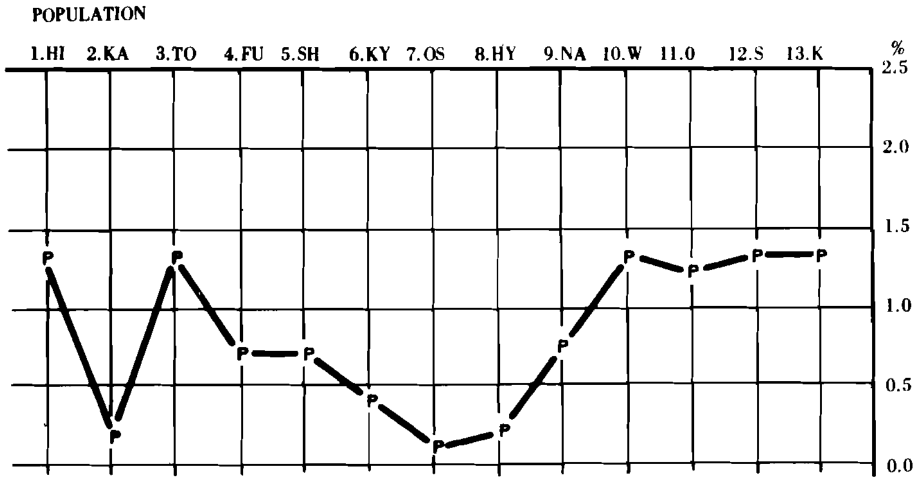


Figure 13. Growth rate of regional population (Case 2).

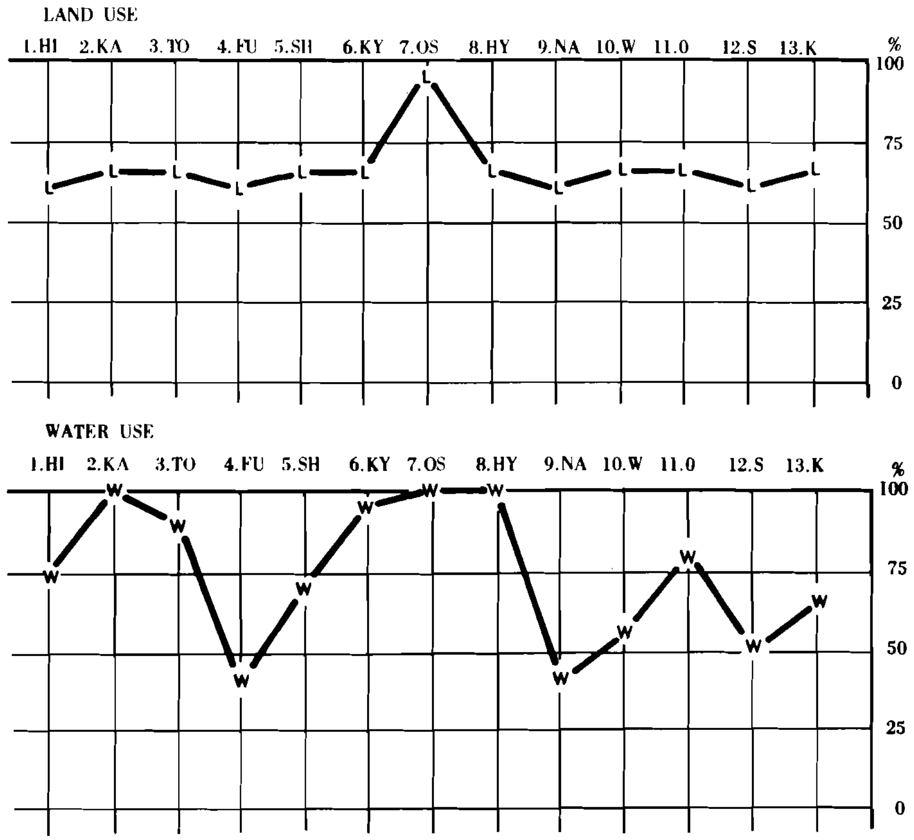


Figure 14. Land and water usage rate (Case 2).

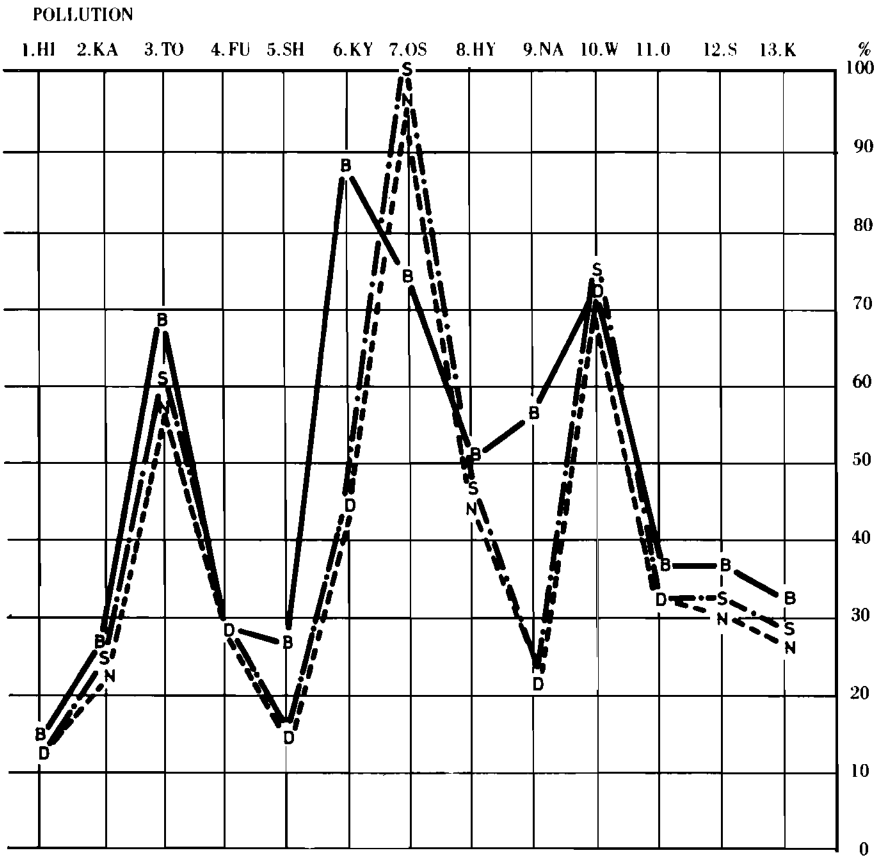


Figure 15. Pollution level (Case 2).

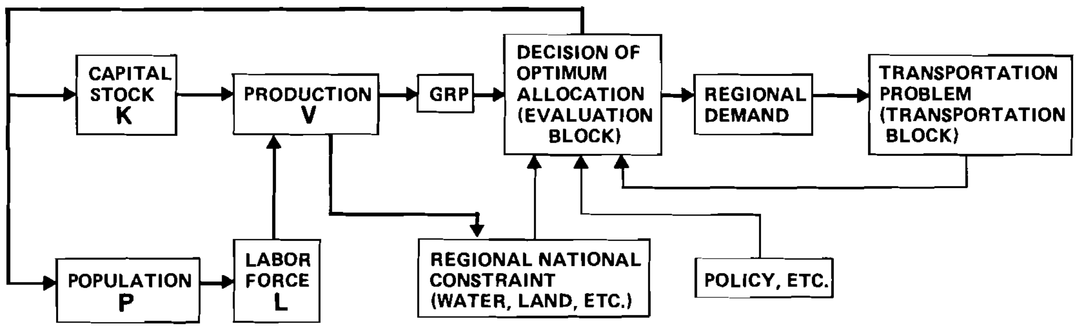
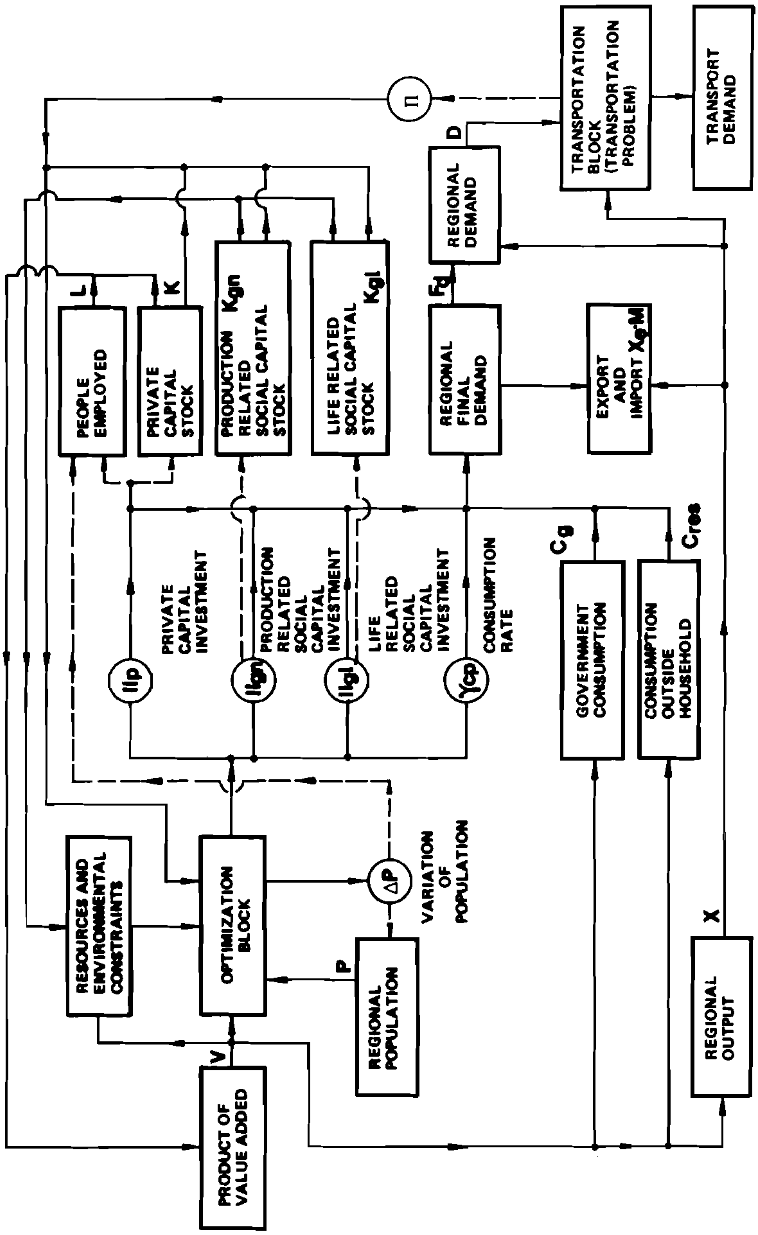

CAPITAL STOCK K
PRODUCTION V
GRP
DECISION OF OPTIMUM ALLOCATION (EVALUATION BLOCK)
REGIONAL DEMAND
TRANSPORTATION PROBLEM (TRANSPORTATION BLOCK)
POPULATION P
LABOR FORCE L
REGIONAL NATIONAL CONSTRAINT (WATER, LAND, ETC.)
POLICY, ETC.

Figure 16.



TRANSPORTATION BLOCK (TRANSPORTATION PROBLEM)
TRANSPORT DEMAND
Π
D
REGIONAL DEMAND
Fd
L
K
PEOPLE EMPLOYED
PRIVATE CAPITAL STOCK
PRODUCTION RELATED SOCIAL CAPITAL STOCK
Kgn
LIFE RELATED SOCIAL CAPITAL STOCK
Kgl
REGIONAL FINAL DEMAND
EXPORT AND IMPORT
Xe-M
Iip
PRIVATE CAPITAL INVESTMENT
Iign
PRODUCTION RELATED SOCIAL CAPITAL INVESTMENT
Iigl
LIFE RELATED SOCIAL CAPITAL INVESTMENT
Ycp
CONSUMPTION RATE
Cg
GOVERNMENT CONSUMPTION
Cres
CONSUMPTION OUTSIDE HOUSEHOLD
RESOURCES AND ENVIRONMENTAL CONSTRAINTS
OPTIMIZATION BLOCK
ΔP
VARIATION OF POPULATION
P
REGIONAL POPULATION
V
PRODUCT OF VALUE ADDED
X
REGIONAL OUTPUT

Figure 17.

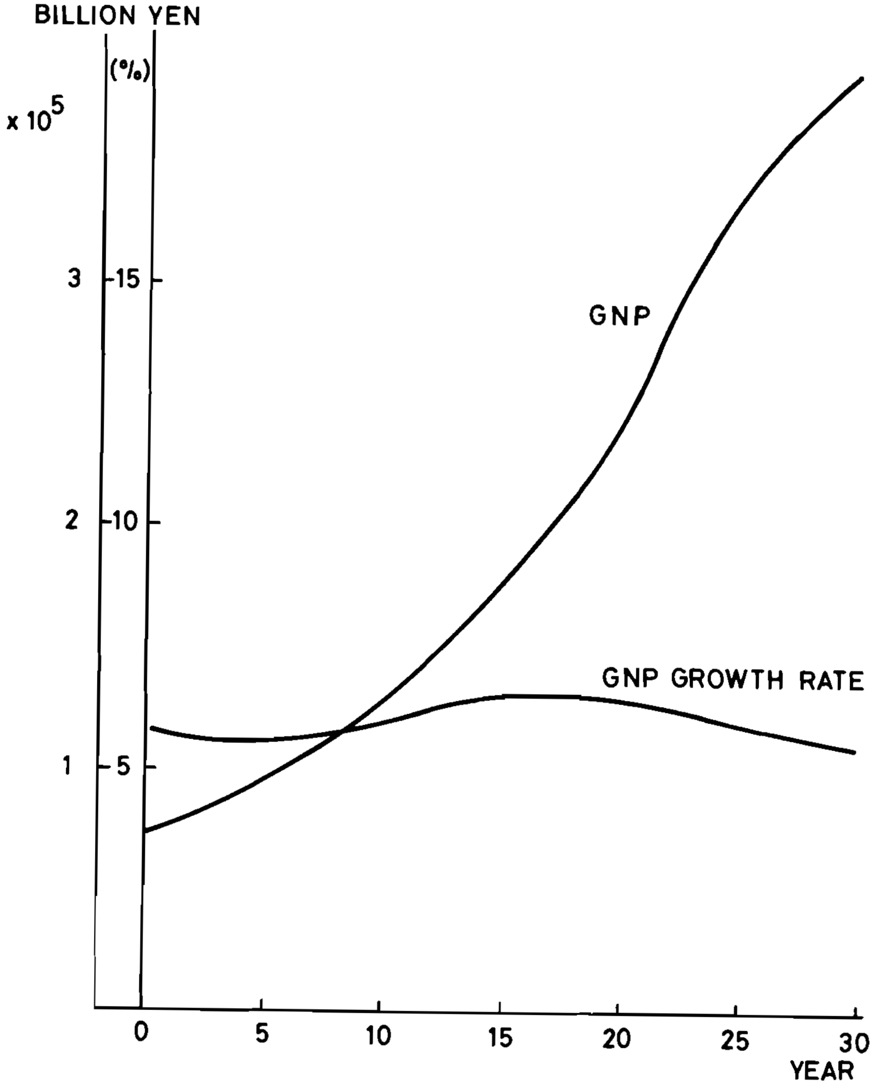


Figure 18. GNP, GNP growth rate.

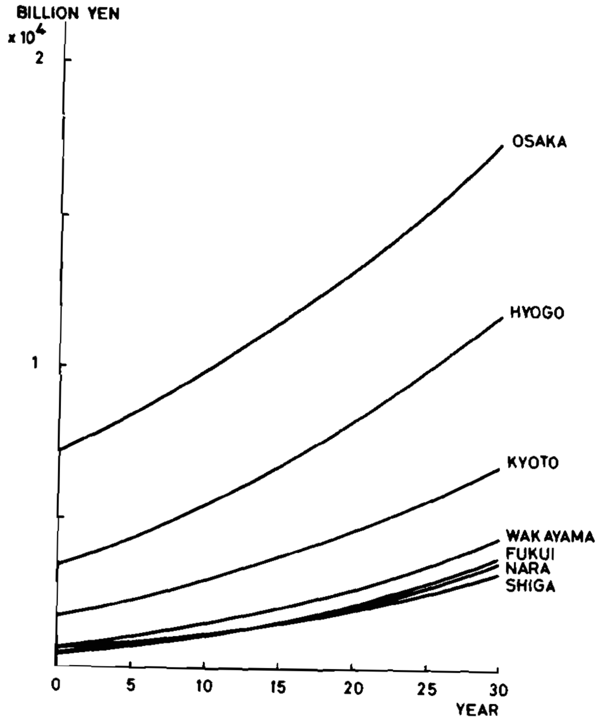


Figure 19. GRP (Kinki area).

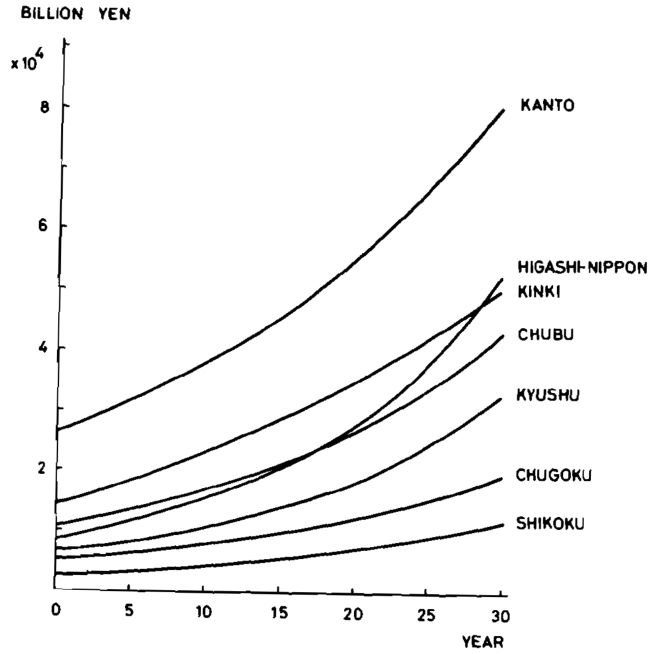


Figure 20. GRP

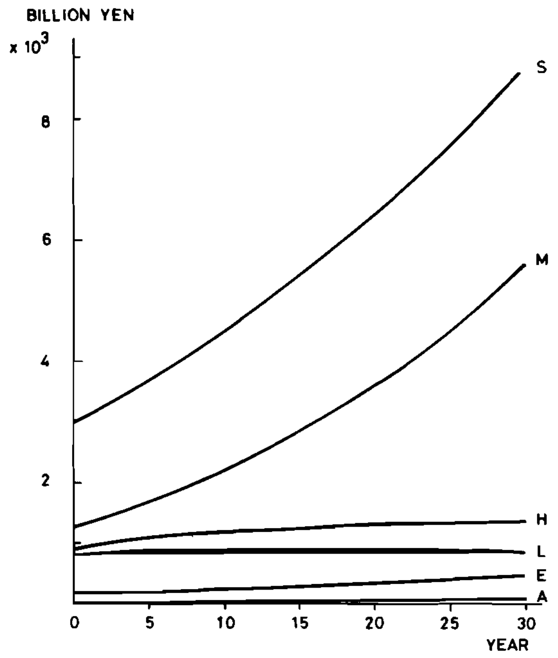


Figure 21. Regional product of value added by sectors (Osaka).

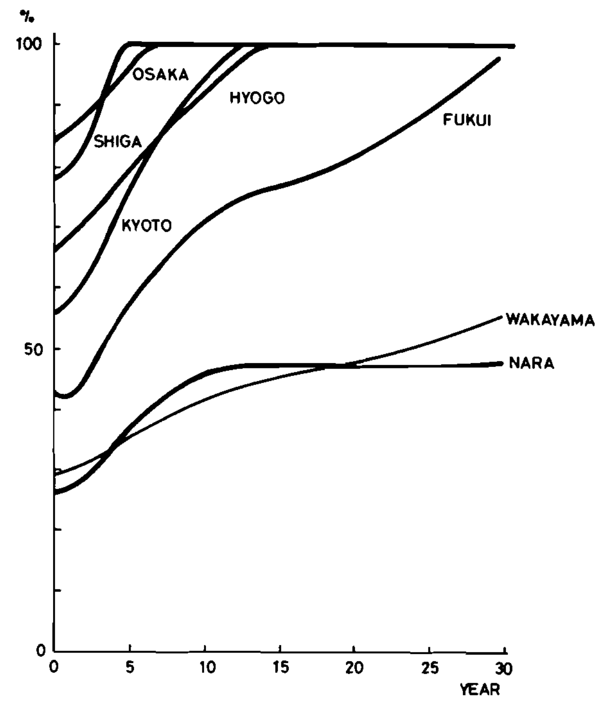


Figure 22. Water use rate (Kinki area).

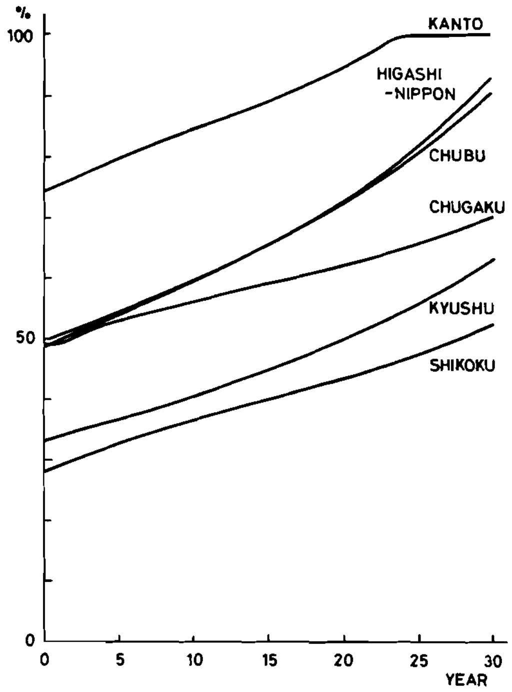


Figure 23. Water use rate (other areas).

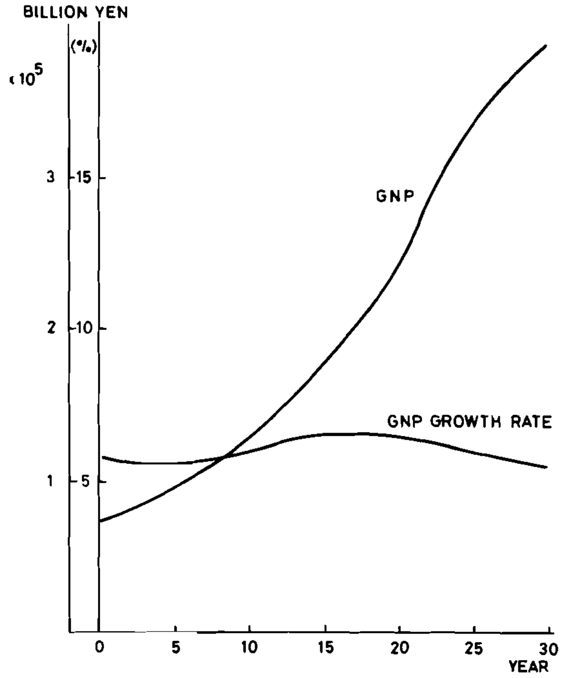


Figure 24. GNP, GNP growth rate.

A Computer Systems Approach to a Regional Development Program for the Local Government of Japan

T. Matsuzaki[†]

SUMMARY

The purpose of this report is to introduce our activities in systems development for experience transfer and comparative studies.

Complexities of a regional problem structure necessitate a systems approach equipped with a flexible hierarchical concept in order that a problem resolution can be reached. Thus, a multitude of approaches have been inevitable in development efforts to establish a regional management system.

At the upper level of a management system is a long-term comprehensive plan that sets a guideline for regional development. A computer assisted dynamic model was developed and used to form a new long-term plan through a number of regional symposia in attaining a general consensus concerning alternative patterns for the future growth.

Since 1972 several opportunities have been given to tackle problems employing a systems approach by using a computer system in cooperative research and development with a local government of Japan, Hyogo prefecture.

A new plan was successfully established in which regional management systems concepts were embedded requiring extensive system development efforts as a natural extension of higher level planning concepts, that is to say development of a regional management system.

INTRODUCTION

Japan has attained today the highest degree of affluence and prosperity in its history as a result of the great strides made by its economy in recent years. This fast growth of the economy, however, has created various social strains. For instance, environmental pollution has become a nation-wide problem, jeopardizing the living environment and the health of the people.

[†]Senior Researcher, Tokyo Scientific Center, IBM, Japan.

The Hyogo prefecture has set its sights on the realization by 1985 of a "New Comprehensive Plan" that would result in the creation of a welfare state. This plan will replace and complement an earlier plan that, when examined in the light of present conditions, proved to lack a sufficiently concrete and systematic attitude toward human lives, social welfare, and cultural requirements.

The New Comprehensive Plan consists of a basic plan and a regional development plan. In drawing up the basic plan, consideration had to be given to the long-term possibilities and limitations of essential societal factors.

In the regional development plan, regional management concepts require the establishment of multidimensional assessment criteria so as to make sensible decisions under uncertain conditions. The factors to be evaluated are not always quantitative. Therefore, it is important that tested value systems of experienced planners should be incorporated into the regional management systems, together with the participation of citizens.

In the first section a statement of problems in Hyogo prefecture is made requiring systems solutions described in the second section. The last section is devoted to case studies introducing some experiences where systems concepts are implemented and institutionalized in a practical situation.

PROBLEM STATEMENT

The Hyogo prefecture is no exception in suffering from complexity of regional problems associated with urbanization, industrialization, etc. Since 1972, we have jointly developed a planning support system in order to cope with such a situation.

Geographical Features in Hyogo Prefecture

Hyogo prefecture is located about 550 km west southwest of Tokyo with a population of about 4,990,000 (as of June 1975) in an area of 8,373.5 km^2. 70 percent of the area is mountainous and covered by forest. The heart of the district is Kobe City with a population of 1,350,000.

To the north is the sparcely populated Tajima region facing the Japan Sea, and to the south is the highly developed region with Kobe City as one of the biggest growth centers of the prefecture.

To the west, Himeji with a population of 420,000 is the hub of the bustling Harima industrial region facing the Seto Inland Sea. The city is bordered by hills to the north that slope gently southward to the coast where steel mills, thermal power plants, petro-chemical, and manufacturing industries dominate the skyline.

In addition to its industrial power, Himeji has an entirely new kind of significance: it is the testing ground for a fresh, exciting experiment using the computer to control one of Japan's most insidious blights: air pollution (see Figure 1).

Complexities and Interrelations in Problems

Urbanization, industrial development, deterioration of the natural and living environment, and regional socio-economic problems are closely related with each other. It was through intensive meetings from April to August 1973 with staff members of the planning department that the regional problem structure was identified as in Figure 2. This structure proved to be applicable both to northern and southern parts of the prefecture with some modifications in parameters.

Urbanization

A population increase resulting from in-migration due to attractivity of urban areas may cause traffic congestion, air pollution, noise pollution, solid waste disposal problems, water pollution, and health damage, leading to an eventual population decrease.

Industrial Development

If the present pattern of industrial development continues without structural change, the natural and living environment may deteriorate owing to every kind of pollution, notwithstanding economic growth and monetary gain.

Natural and Living Environment

The natural environment such as air, water (rivers and sea), landscape (forest, wood, etc.) may be polluted by industrial development and urban sprawl. The living environment in urban areas becomes uncomfortable through noise and vibration from railroad and automotive traffic, indifference to aesthetic concerns, congestion, etc.

Associated Social Problems

As a consequence of migration into and out of urban and industrial areas social indices of the population increase or decrease with some associated social problems (see Figures 3 and 4).

SYSTEMS SOLUTIONS

A multitude of systems solutions with hierarchical concerns should be devised parallel and integrated so that solutions can be implemented and institutionalized, maintaining flexibility and reliability.

Objectives in a Systems Approach

The major objectives in a systems approach are two-fold: to identify the structure of regional systems, and to establish future plans on the basis of a regional management system with the consensus of the people of the region.

Identification of Regional System Structure

The regional system structure to be identified is categorized as in the following:

- value systems of the people of the region,
- interrelations of regional problems.

Owing to the recent economic growth, value systems, and behavioral patterns of the people have been diversified with multiple objectives by the following factors:

- age,
- sex,
- education/professional experiences,
- regional block,
- religion,
- etc.

Therefore investigation into value system structures is essential for a regional planner to work out effective alternative regional development plans, at a first stage of planning.* The regional model should at least treat the structure of the value system and its problems.

---

*The Hyogo prefecture conducted an extensive survey of social indicators from 1972 to 1973.

Societal Conflict Resolution by Regional Management System

Regional development projects are usually approved as a social selection and put into execution after a process of societal coordination. Adequate and timely information is essential to accelerate the processing of the coordination. Without these coordination processes, plans that are feasible from economical and physical points of view might be socially infeasible.

In the formation of regional living space such groups as the following are concerned:

- national government,
- prefectural government,
- cities,
- towns,
- private enterprises,
- national enterprises,
- people of the region,
- etc.

Coordination processes become increasingly important, year by year, as conflicts among those concerned in the regional development project become more difficult to solve.

Major Concepts in Systems Approach

In March 1975 the Hyogo prefectural government established a new long-term comprehensive plan,* called the "Living, Cultural, and Social Plan in A Perspective for the Year 2000". This revealed the need to develop a method of preparing a comprehensive management system for regional development. And, in the text of a new plan, it is clearly stated that the regional management system should be developed so that a new planning philosophy could be implemented and institutionalized.

We have designed the system in such a way that an input regional development plan will be decided upon in regard to its own particular goals with the consensus of apparently conflicting concerned bodies. A major underlying concept is "societal coordination through a multistage assessment process".

---

*Case study 1 will be devoted to the description how a systems approach assisted in establishing a new plan.

Being different from plans of private enterprise, public policy programs are characterized by, for example, indivisability, long-term influences, mutual relations among concerned decision makers, and diversity of purposes, along with other qualitative factors to be taken into account. And public policy programs also require that purposes, instruments, and processes be well balanced in a management procedure. A systems approach is expected to attain goals in view of these characteristics of public programs confronting changes of regional society (see Table 1).

Regional Management System

The prefecture's comprehensive plan specified basic guidelines for regional development philosophies and concepts to be realized. This comprehensive plan is expected to function as a concrete operational instrument for the formation of a desirable living environment in all the respects of human living.

A Multilevel and Multistage Assessment Process

A multilevel and multistage assessment concept is proposed for regional development projects, and it is to aim at the resolution of societal conflicts among several concerned bodies including the people of the region. A hierarchical systems concept in modern control methodologies is the basic idea of this approach.

Applied systems analysis methodologies are utilized, assisted by modern computer technologies such as the interactive handling of data and models representing data generated on a graphic display system in order to enhance communication between a computer system and policy planners. And an organizational system is to be designed in such a way that systems flexibility should be maximized in an operational environment. Among systems analysis techniques, prediction methods of various kinds play very important roles on the basis of data stored in a well-structured manner in the computer system. Adverse effects as well as positive socio-economic effects are projected for the necessary time period.

The assessment system model is one of the most difficult to be developed and operated. The method to overcome the difficulties is an iterative and spiral use of a total assessment system with the participation of the concerned people. Gaming concepts are implicitly implemented during these procedures.

Figure 5 shows a conceptual input-output relationship in a regional management system for a regional development project planning. The regional management system is broken down into subsystems to be supported by system tools and instruments as in Table 2.

System Tools and Instruments

As the regional plan is followed from left to right on Figure 5, the plan element is broken down into several constituent elements. At the same time, uncertainties associated with the plan will be decreased and minimized by human intervention for interaction in the processes. Thus, a conceptual regional development plan evolves, gaining from participation by decision makers in order to attain regional concensus.

The Regional Development Planning System is composed of a Regional Development Project Impact Assessment System (PIAS) as an applied system and a Computer Assisted Regional Development Planning System (CARPS) as a tool of the Regional Development Planning System. The PIAS and CARPS are the systems to prepare project information for coordination activities. PIAS is the operating system, assisted by CARPS (Computer System) in which human factors and mechanized factors are interactively combined (see Figures 6 and 7).

A Computer Aided Regional Development Planning System

Scope of Applied Systems Analysis: Physical development project plans are classified as is described in Table 3.

Feasible Scope of Systems Approach: The feasible scope of a systems approach is investigated in a matrix with the maturing process of plans as columns and with the decision making process as rows, as in Table 4.

From the viewpoint of the maturing of a plan, a planning process consists of six stages, from the comprehensive regional development planning, which shows the version of entire regional development, to project designing. At each of these stages, a proposed plan or project is evaluated by comparison of alternatives, judgments and selections. A selection among alternatives has relatively smaller significance after the stages of the basic envisioning and planning of projects. Since a decision to carry out a project has already been made in these stages, subsequent selections are related to the judgment on details and minor coordination among fields. However, the process of selection among alternatives has an extremely important role before these stages. That is, a decision must be made whether a project in question is feasible and whether it should be adopted. It is at this stage that various groups connected with a project come to oppose one another strongly. This explains why assistance from this system is necessary and possible in these stages.

Concept and Functions of System: PIAS is applied to systematic planning, and CARPS is a tool for assisting this system.

The relation between PIAS and CARPS and its functions are schematically shown in Figure 8. The role of the computer aided system is to provide planning staff with adequate data in a timely fashion. Thus, it will enhance and assist the functions of the Regional Development Planning System.

Enhancement of Citizens' Participation

In establishing a long-term comprehensive plan, warning information was used as one effective mean for motivating concerned people to participate in symposia on the plan formation processes (see Figure 8).

Meanwhile, the Environment Agency of Japan prepared a bill to be proposed to the National Diet, that will establish a basic government policy on a total environmental impact assessment where some scheme of participation may be taken into consideration. The system we are proposing now is expected to be consistent in its philosophy and principles with that of the Environment Agency of the Japanese Government.

Some Features in a Computer Aided System

CARPS has some features of a computer aided system to assist the organic linkage of the systems constituting the Regional Development Planning System according to user's problems and to assist integrated system operation. Users give instructions to a computer through a conversationsal operation function that calls out the functions that assist the solution of problems and links the functions organically in a flexible way. Structures of the regional development planning system and input-output relations are shown in Table 2 and Figure 8.

Computer Mapping

Spacially distributed geo-data are handled and displayed. A function is prepared for computer mapping. This function is used to load, accumulate, retrieve, and display geo-data. With this function, the system can assist a plan with areal expanse. Geo-data are assumed to consist of "map", which expresses geographical relations and "Regional Data", which are the attributes of maps. Geo-data processing is given flexibility by dividing maps into "regional division", "expression of divided area", and "expression of boundary".

Model and Data Handling

Independence of model and data is established as a basic concept for the processing of geo-temporal data in modeling and computer simulation. The model operation function that assists modeling and simulation allows planners to use various models easily and to link them conversationally by a variety of functions such as description of model structure, description of data, quotation of other models, quotation of data outside model, specification of a part of model definition at execution time, conditional simulation, and sequential simulation.

The data management function makes models, such as of the impact prediction of a composite project, and assists simulation. It also inputs, retrieves, and processes geo-data and time-series data effectively and flexibly. It provides data as exogenous variables of models and assists geo-data retrieval as well.

CASE STUDIES - EXPERIENCES IN SYSTEMS DEVELOPMENT

We have had experience in the development of regional planning support systems since April 1972, including:

- A computer aided long-term comprehensive planning system (April 1973-March 1975);
- A regional management system assisted by computer system (January 1975-January 1976);
- An air pollution prediction and control system (April 1972-March 1973);

as described in Figure 9.

A Computer Assisted Long-Term Comprehensive Planning System by Hyogo Dynamic Model

The prefecture need a New Comprehensive Plan. The activities were carried on with the participation of both the Council for the Comprehensive Plan, which was an advisory body to the governor, and the general public (see Figures 10 and 11).

A system dynamic approach is taken to assist the planner by giving him as much information as possible in policy making. This approach will also contribute to solve the problem in studying dynamic regional behavior. In this system, two levels of model structure are employed: one is for the whole prefecture, the other for the industrialized region along the coast of the Seto Inland Sea. The prefectural model will offer information concerning the maximum capacity of the prefecture. The regional model will mainly be used to give warning. By comparing the results of computer simulation using these models, effective data will be collected, contributing to policy making.

There are four major sectors in the simulation system: the population sector, the environment pollution sector, the industry sector, and the natural resources sector. The output results of the computer simulation were submitted to the regional symposia with the inhabitants in order to establish a comprehensive plan for the coming 12 years through consultations.

Procedures in Systems Planning

Systems approaches were made in a cyclic manner with steady and repeated examination, as follows:

- Systems exploration for the purpose of understanding the structure of problems;
- Systems planning as a step toward the establishment of a fundamental direction putting order in the way of thinking and offering alternatives in problem solving;
- Feasibility study for probing the technical possibilities thoroughly and from various aspects, along with the development of a prototype system;
- Documentation for the introduction and guidance required for the implementation and for communication purposes.

The process of model development was as follows:

- To define problems by scenario writing;
- To select systems variables;
- To divide the problem area into such sectors as population, environmental pollution, industry, resources;
- To establish the structure in the form of a flow diagram, and, at the same time, to frame policies examining positive and negative feedback loops;
- To establish parametric relations by reexamination of data availability and collection of data;
- To carry out programming and to check major variables by sensitivity analysis;
- To run the simulation of a total model;
- To edit output material by means of diagrams;
- To validate the model by available data.

Multiple Level of Model Structure

Hyogo Dynamics includes two models; one is a model for the whole prefecture and the other is of the industrialized coastal area along the Seto Inland Sea.* The first model will offer data concerning the maximum capacity of the prefecture. The second is mainly used to give warning data. Since 70 percent of the population and more than 90 percent of the industrial production are concentrated in this coastal area, the problem areas described in the model define the most grave ones in the Hyogo district.

The four major sectors in the simulation system are as follows:

1) Population Sector:

The population model expresses birth, growth, death, and in- and out-migration in terms of the different age groups, which were divided in five-year groups. In addition, two groups of new born infants and a group of persons 65 years old were established.

2) Industrial Sector:

- Industrial Model: This model is for the secondary industry which is closely related to the problems of environmental pollution, water demand, and personal income in the prefecture.

- Traffic Model: The traffic model is designed to describe problems of an urban transportation system by automobile. In this model the traffic volume has been computed by summing up the number of trips by passenger car, buses, and trucks.

3) Environmental Pollution Sector:

This sector includes four problem areas such as pollution of the air, ocean, rivers, and pollution from solid wastes.

4) Resources Sector:

- Food Model: This is to examine a balance of the amount of food consumption and food production within the prefecture. An approximate estimate of productivity is made in agriculture and fisheries.

- Water Resources Model: The model examines the balance between supply and demand of water by comparing the two variable values of the potential water resources supply and its demand.

---

*The industrialized coastal region includes the following cities and towns: Amagasaki, Itami, Takarazuka, Kawanishi, Ashiya, Kobe, Akashi, Kakogawa, Takasago, Himeji, Aioi, Ako, and Tatsuno (Cities); Harima, Inarimi, Mizu, Taishi, Ibogawa, and Kamigouri (Towns).

- Energy Demand Model: This model was added to the previous one in March 1974, in compliance with a request of Council members. The request was triggered by the worldwide energy crisis. Since energy supply remains uncertain, it is difficult to approach the problem from the viewpoint of supply. Therefore, in this model demand forecasting is done by dividing it into the fields of industry, transportation, public welfare, etc.

Establishment of a New Plan Through Participation of People of the Region

Warning by Simulation Results: Population and Industry: The standard run indicates that the population of Hyogo prefecture will reach 630 million in 2010, and will decrease gradually thereafter. The proportion of aged people (65 years or over) will reach 20 percent in 1995 and will continue to increase thereafter. These results imply that a further and thorough study on the social status of the aged and their welfare should be carried out.

Industry is a major cause of environmental pollution. A not too rapid but stable growth of industry thus becomes desirable. Therefore, it is necessary to promote a shift to an intellect-oriented industry structure to realize this equilibrium of industrial growth (see Figure 12).

The Environmental Pollution: The forecast shows that in the year 2020, without technical innovation, air pollution along the coast would be six times as severe as it is today, river pollution along the coast nine times, and ocean pollution five times (see Figures 13 and 14).

Overpopulation in the City: Population density in the city area would be four times higher in the year 2020. This indicates that innovative city development and control of population and industry growth should be recommended (see Figure 15).

Water Resources: Water shortage in the industrialized coastal area would become much more severe. The conversion of the present industrial structure to one oriented toward conservation by the recycling of water for industrial use is necessary (see Figure 16).

City Transportation: Traffic congestion would be 2.3 times more severe in 1985 and eight times in 2020 than it is today.

In the year 2000 the number of passenger cars will reach saturation level. This shows that a further and thorough examination of the transportation system, with emphasis on public transport facilities, should be carried out.

A Computer Aided Regional Management System

The decision to adopt the new plan supported by Hyogo Dynamics was made by the prefect's governor in March 1975. A joint research contract to develop PIAS-CARPS was effective from January 1975 to January 1976. The internal demonstration of a prototype system was conducted on 23 December 1975 in the computer room of the Planning Department of Hyogo prefecture (see Figure 17).

A Project Impact Assessment System

ADAMS (A Data Base Management): Regional data such as population, employment, etc. are stored by 52 subregions in IMS (Information Management System, Program Product supplied by IBM) and retrieved through character display terminals using functions in CARPS (see Figures 18 and 19).

Some geographically distributed data, like construction standards of high schools and environmental quality standards,* play a screening role for regional development projects, used in the basic management system.

Effect Prediction System: Some econometric models as well as statistical analysis methodologies are developed to be used in an interactive fashion by using model and data handling functions of CARPS, developed by M. Ohkohchi and M. Udo researchers in the Tokyo Scientific Center, jointly with Hyogo staff members.

Assessment Model: T. Matsuzaki, as a member of EIS (Environmental Impact Statement) Study Committee in the Environment Agency of Japan, began a survey of the models to be used in the assessment system. Some of the work was conducted by the Environmental Impact Assessment Study Team (T. Matsuzaki as General Secretary) of the Japan Operations Research Society. A check list and matrix approach are being studied along with physical models in pollution diffusion.

---

*The Environment Agency and the Hyogo prefecture are preparing to develop an environmental quality standard for EIS (Environmental Impact Statement).

A Computer Aided Regional Development Planning System

CARPS has been developed successfully as a supporting system to be used in PIAS. Reports are now in preparation for dissemination under the joint research contract.

A Prototype System Development

Final demonstration will be given at the IFHP (International Federation for Housing and Planning) Conference in the Hyogo prefecture in May 1976.

An Air Pollution Prediction and Control System

Japan has been faced with serious environmental problems associated with rapid regional development. Several counter measures have been taken to cope with some of the problems, such as a concentration, regulation, and a total emissions control. However, these alone are not enough to resolve the complex problems involved. A system of environmental assessment is indispensable to study and to determine in advance the environmental impact of such activities that affect the environment during regional development (see Figure 20). However, experience with environmental assessment is still limited and many points concerning methodology, factors to be checked, etc., await further study.

In June 1972 the Cabinet approved the idea of making preliminary assessments, when necessary, of how various kinds of public works and regional development would affect the environment. This idea is even closer to being implemented now that the Seto Inland Sea Conservation Law has been enacted. In fiscal year 1974, efforts will be made to develop the techniques and set the guidelines for such assessment. A man machine system approach was employed to assist the planner in assessing the projects impact on the regional environment in line with the Total Emission Control Law for air pollution abatement. The graphic display system was introduced as a communications medium between planners and the computer simulation system. Himeji city, with a population of 420,000, was selected for the validation of the systems approach.

Plant Site Evaluation

Urban and regional management concepts necessitate the establishment of multidimensional assessment criteria in order for the planners responsible to make rational decisions on the strategic development plan of the subject area, under interdependent and complex uncertainties. The factors to be evaluated are not always quantitative. Therefore it is essential that the tested value systems of experienced planners be incorporated into the urban management support systems.

One of the most effective system solutions is given by introducing an interactive systems approach. Our system is designed in such a way that a human decision is assisted by investigating the air pollution concentration patterns at the ground level over the subject area. The Gaussian plume model is used on the basis of a well established statistical method. Emission data are obtained in compliance with the agreement with Hyogo district and Himeji city for experimental research use.

The following sections of this paper will be devoted to an explanation of the modeling of diffusion phenomena associated with the local meteorology, some supporting data for the validity of our approach, and to the functions of computer systems.

Simulation of a Multisource Air Pollution Diffusion: As the best way of approaching the problem, we have employed the Gaussian plume model in the simulation area, about 20 × 20 km along the coast of the Seto Inland Sea.

In developing the simulation method, the SO_2 concentration is calculated by the linear summation of the result obtained from the Gaussian plume model for a single stack under the conditions such that the prevailing wind blows consistently and diffusion process is in a steady state. We have performed modifications on the Gaussian plume model in order to use it successfully from the following point of view:

- space-dependency of the meteorological parameters;

- time-dependency of the meteorological parameters.

From the space-dependent point of view, the meteorological parameters are modified such that rather than one uniform wind direction two wind directions in the western part and in the eastern part of Harima Plain are used, and rather than a single atmospheric stability class a concept of two atmospheric stability categorization schemes for high stacks and low stacks is introduced. In the simulation area, two atmospheric stability classes must have been considered because there are some stacks taller than 100 m. The atmospheric stability class table for high stacks is newly introduced by analyzing the observed test data through a trial and error approach. The table for low stacks is almost the same as the Pasquill's table. The dispersion coefficients σ_x, σ_y are used from the result of the St. Louis dispersion study. From the time-dependent point of view, the meteorological data of the simulation area are analyzed, and classification of the meteorological conditions is conducted so as to find the condition during the time of "episode".

Based on the modified Gaussian plume model, the eight hour average concentration of SO_2 is calculated by the Tokyo Scientific Center. Figure 21 shows the isopleths of the simulated eight hour average concentration in the simulation area on May 18, 1972. The points with numeric signs show the monitoring station. The southwesterly prevailing wind from the sea during the eight hour day period results in twin peaks in the concentration along the prevailing wind direction.

The observations of concentration are compared favorably with the simulated results. The concentration of SO_2 is given linearly.

Interactive Simulation System of Air Pollution (ISSAP): An interactive simulation system of air pollution (ISSAP) has been developed to show the efficiency and feasibility of an interactive systems approach to solve the air pollution problem. The ISSAP also provides the user with an evaluation tool for planning related to air pollution, such as urban planning and environmental control planning.

A schematic overview of the ISSAP is given in Figure 22. The pollutant diffusion model adopted in the ISSAP is based on the widely used and well-established Gaussian plume formula, which is practical to be used for short-range planning in respects of data handling, computing time and precision. As the primal objective of the ISSAP is not to validate a specific model, but to demonstrate usefulness of the interactive systems approach, the model is not necessarily turned up so as to fit on a specific area.

The data used by the model consist of three types of data, i.e. stack data for each stack, meteorological data and area data.

Graphical representation of simulated results is given on a cathode ray tube display (IBM 2250 graphic display unit), and moreover, any parameter of the model can be easily retrieved and modified interactively through the display in the course of simulation. It is coded by M. Ohkohchi in the Tokyo Scientific Center.

A typical representation on the display is given in Figure 23. Meteorological parameters shown on the display are as follows; atmospheric stability class=2.5 (slightly unstable), wind direction=202.5^{o} (SWS), and wind speed=5.0 meters/second. Subject stacks, which are built in for demonstration use only, are represented by mark 'I', and the stimulated SO_2 concentration pattern is represented by contour lines whose interval is 0.02ppm. Maximum concentration on the subject area is 0.108ppm at the point marked 'M'.

Interactive functions of the ISSAP are listed in Table 5. To show the usage of these functions, a typical operation of "STK PAR" function is discussed.

After selecting the "STK PAR" from the menu on the display by the light pen, in response to pointing at a stack mark "I" on display with the light pen, the corresponding stack data is retrieved on the display. Any parameter displayed may be modified by light pen selection and keying in, and then the effect of the change is simulated. For example, by changing the emission rate of a stack to zero or by changing the position the effect of the stack's removal can be simulated. Some typical results are shown in Figure 23.

ACKNOWLEDGMENT

The author would like to express his gratitude to H. Knop, Leader of the Management and Technology Research Area at IIASA, for offering an opportunity to present and discuss international common problems in IRD programs (Integrated Regional Development), and for encouraging communication of experiences with other projects such as the BRATSK-ILIMSK project to develop the Siberian region.

The author also expresses his gratitude to the staff members of the planning department of Hyogo prefecture for their enthusiastic effort in developing planning support systems with the Environment Control Project Team in the Tokyo Scientific Center, IBM Japan, and also to the D.G. -Kinki Team in Kyoto University, led by Y. Sawaragi, for its interdisciplinary research activities jointly with such international organizations as IIASA, IFAC, IFIP, WERC, IFORS-TIMS, etc.

Bibliography

Environment Agency, *Quality of the Environment in Japan*, Government Printing Office of Japan, 1974.

Matsuzaki, T., S. Ogasawara, and Y. Sawaragi, A Computer Assisted Long-Range Comprehensive Planning System for a Regional Project Impact Assessment: A Subsystem of a Regional Management System, in *Issues in the Management of Urban Systems*, CP-75-4, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1975.

Matsuzaki, T., M. Ohkohchi, M. Udo, and S. Ogasawara, An Air Pollution Prediction and Control System for a Regional Environmental Impact Assessment: A Conversational Approach Through Computer Graphics, *Proc. of the 1st World Congress of Environmental Medicine and Biology*, UNESCO, Paris, 1974.

Planning Department, Hyogo Prefectural Government and Tokyo Scientific Center, IBM Japan, *Concept of Regional Development Planning System: An Assessment Concept as Means for a Societal Coordination Process*, Tokyo Scientific Center Report GE18, 1826, 0, IBM Japan, 1975.

Sawaragi, Y., and T. Matsuzaki, A Computer Systems Approach to the Assessment of Regional Project Impact on the Environment in *Proc. of International Congress of Scientists on the Human Environment (HESC)*, Kyoto, 1975.

Shiina, T., *A Computer Systems Approach to an Integrated Regional Planning Project and Environmental Planning*, World Environment and Resources Council (WERC) Conference, Brussels, 1976.

Shiina, T., T. Matsuzaki, S. Ogasawara, and Y. Sawaragi, A Computer-Assisted Long-Range Comprehensive Planning System for a Regional Project Impact Assessment in Land Use Planning, IFAX Sixth Triennial World Congress, Boston, 1975.

Table 1. A systems approach and methodology.

A) In Applied Systems Analysis

Public Policy Planning

- As a Societal Coordination Process

Regional Development Project Impact Assessment

- With a Land Use and Environmental Control

B) In Computer Systems

Interactive

- Model Handling
- Data Management

Computer Mapping

- Geographically Distributed Data

C) In Organizational Systems

Citizen's Participation

- In Planning Process

Structured Approach in Systems Development

- To Enhance Software Productivity

Table 2. Functional characteristics of a regional management system.

Subsystem	Functional Characteristics	Methodologies
Basic Management System	- for preliminary screening and filtering - from financial, land use condition, and environmental quality standard point of view - handling spacially distributed regional data (environment and resources constraint)	- mesh-data analysis - support by human judgment - remote sensing and image processing
Effect Prediction System	- for interrelated regional project impact estimating - on the basis of dynamic regional behavior - referring to socio-economic status at the national level	- macro and micro economic model - system dynamic model - environmental model
Assessment System	- to evaluate positive and negative (adverse) effects simultaneously - in a multidimensional fashion	- checklist method - matrix method - utility functions
Societal Coordination System	- for conflict resolution - among interested enterprise bodies - by citizens' participation	- gaming/conferencing simulation - regional symposium

Note: Input regional development project plans should pass the above series of subsystems consecutively and/or spirally to be finalized.

Table 3. Classification of physical projects.

Classification	Contents
Area Development	Industrial community, residential community, etc.
Facility Improvement	Single Facilities (small-scale development)
Network Formation	Service water and sewage system, roads, railroads, etc.
Conservation and Management	Conservation of natural parks, mountain conservation, water conservation, etc.

Table 4. Feasible scope of a systems approach.

PROCESS OF DECISION MAKING / PROCESS OF MATURING	TARGET SETTING		SEARCH FOR SOLUTION		SELECTION OF ALTERNATIVE	
	PROBLEM DEFINITION	SETTING OF TARGET LEVEL	ALTERNATIVES	PREDICTION	ASSESSMENT	SELECTION
1. COMPREHENSIVE DEVELOPMENT PLAN	(M)	(M)	○	●	●	(M)
2. DEVELOPMENT PROJECTS	(M)	(M)	○	●	●	(M)
3. PROJECTS	(M)	(M)	○	●	●	(M)
4. BASIC PLAN OF PROJECTS	(M)	(M)	○	●	●	(M)
5. REGIONAL EFFECT IMPLEMENTATION PLAN	(M)	(M)	(P)	(P)	(P)	(M)
6. PROJECT DESIGN	(M)	(M)	(P)	(P)	(P)	(M)

BASIC CONCEPT (rows 1–4)

PROCESS OF SELECTING PLAN (rows 1–4)

PROCESS OF DETAILED PLANNING & DESIGN (rows 3–6)

Boxed cells (ALTERNATIVES, PREDICTION and ASSESSMENT, rows 1–4): SCOPE OF SYSTEM APPLICATIONS

● ASSISTANCE BY SYSTEM

○ SYSTEM PARTLY USED

(M) MAN'S JUDGMENT

(P) ENGINEER'S WORK

Table 5. Interactive functions of ISSAP.

FUNCTION NAME	FUNCTIONAL DESCRIPTION
MET PAR	to change meteorological parameter(s)
STK PAR	to retrieve (and change) stack parameters of a stack pointed by the light pen
NEW STK	to add a new stack to the present stacks
AREA	to display (and change) parameters of the boundary and mesh grid system of the subject area to be simulated
LEVEL	to change how to draw the contour lines
DISPLAY	to erase or display figure(s) of selected type(s) on the CRT screen
PRINT	to print out the results calculated by the diffusion model
SAVE	to save the present parameters used by the model and the calculated results
RESET	to reset the status of the model to the last saved

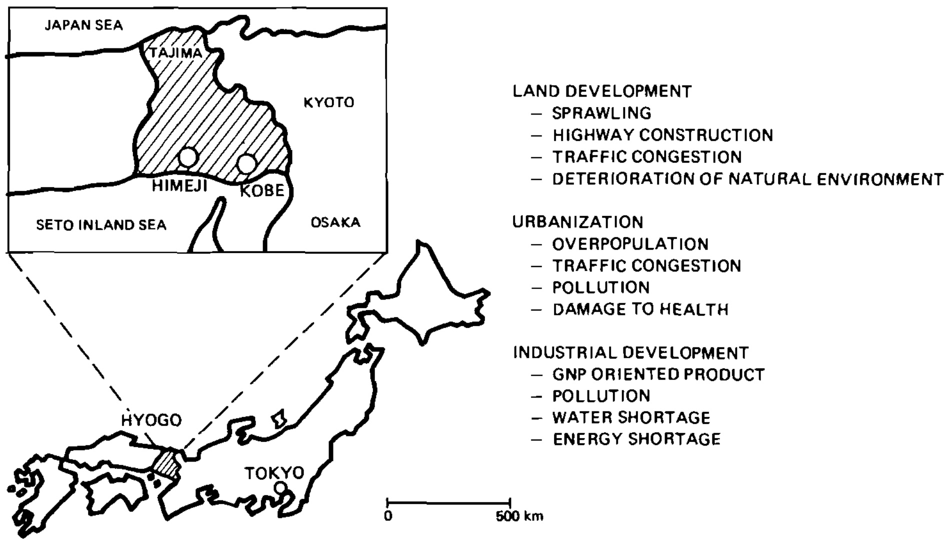


Figure 1. Problem statement--Hyogo Prefecture as a miniature of Japan.

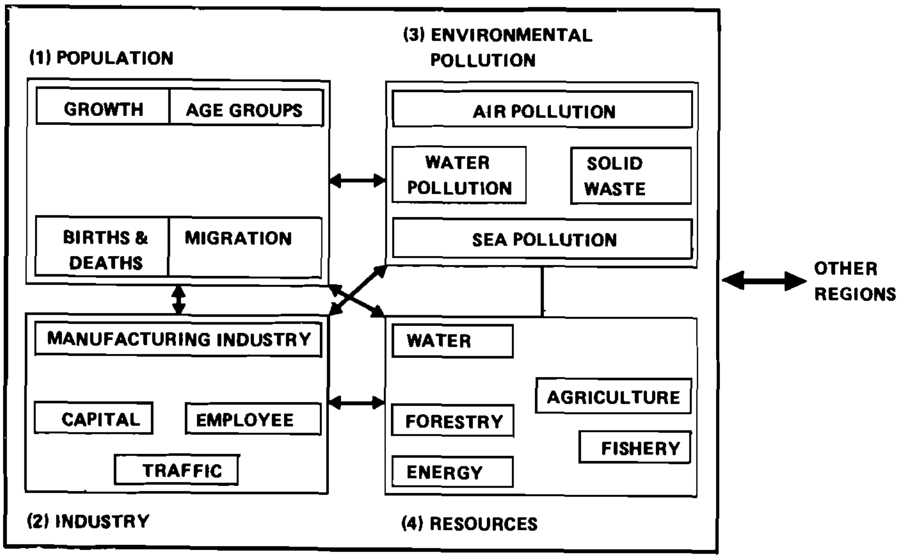


Figure 2. Complexities and interrelations in problems.

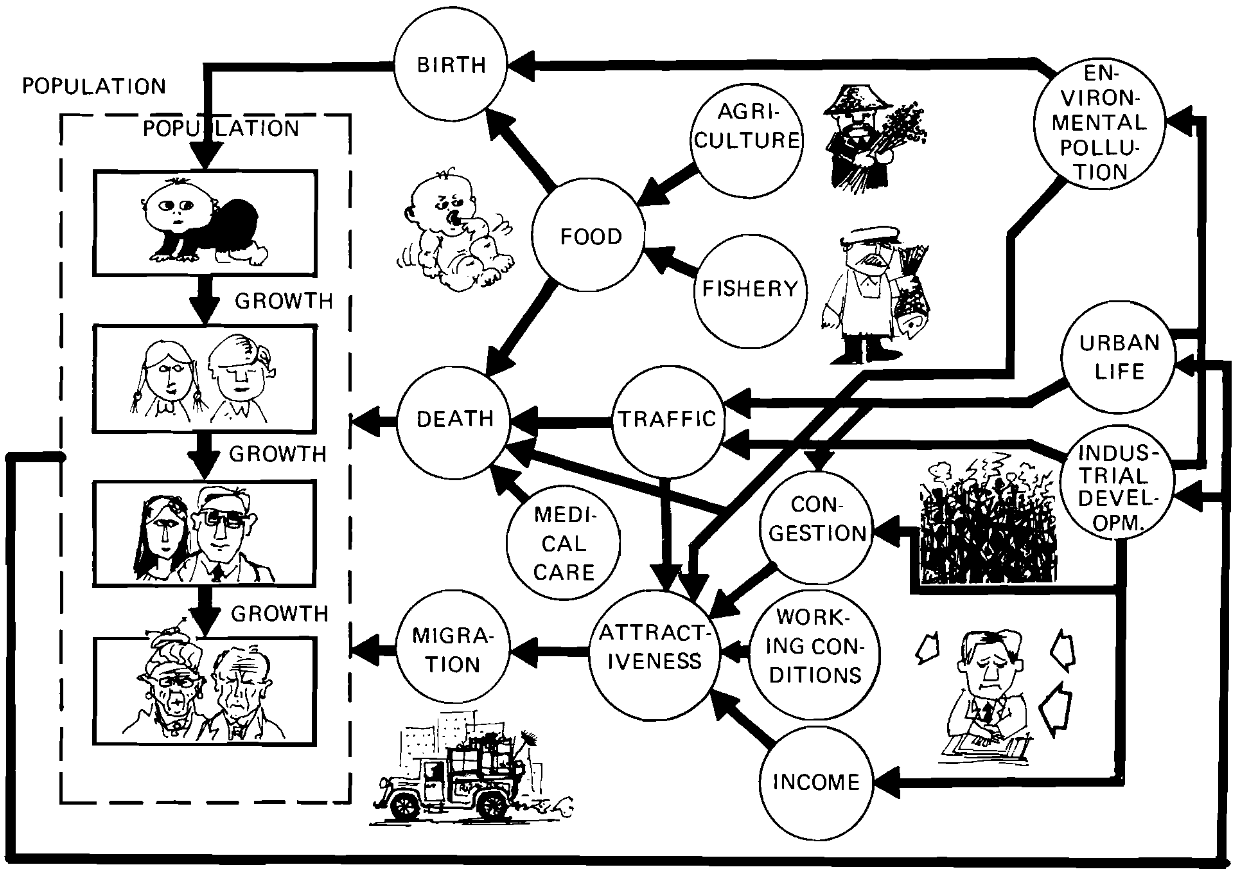


Figure 3. Natural and social changes in population associated with urbanization and industrial development.

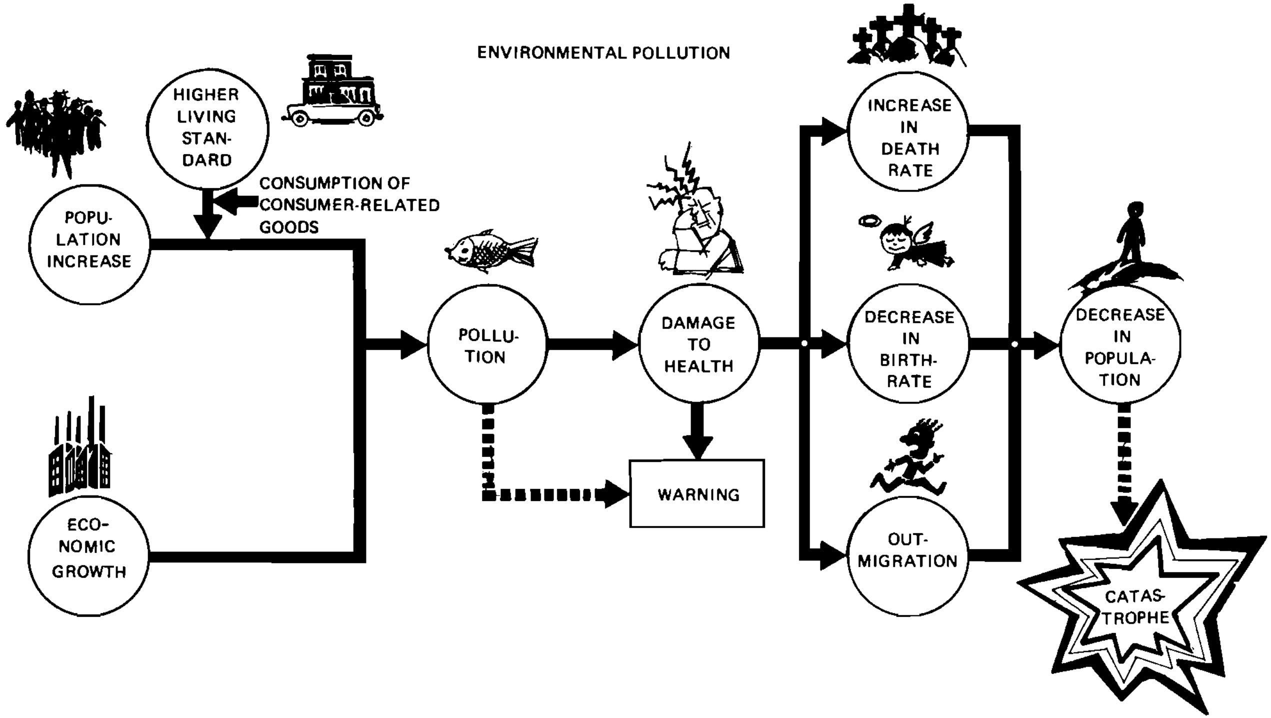


Figure 4. Environmental deterioration by urbanization and industrial development.

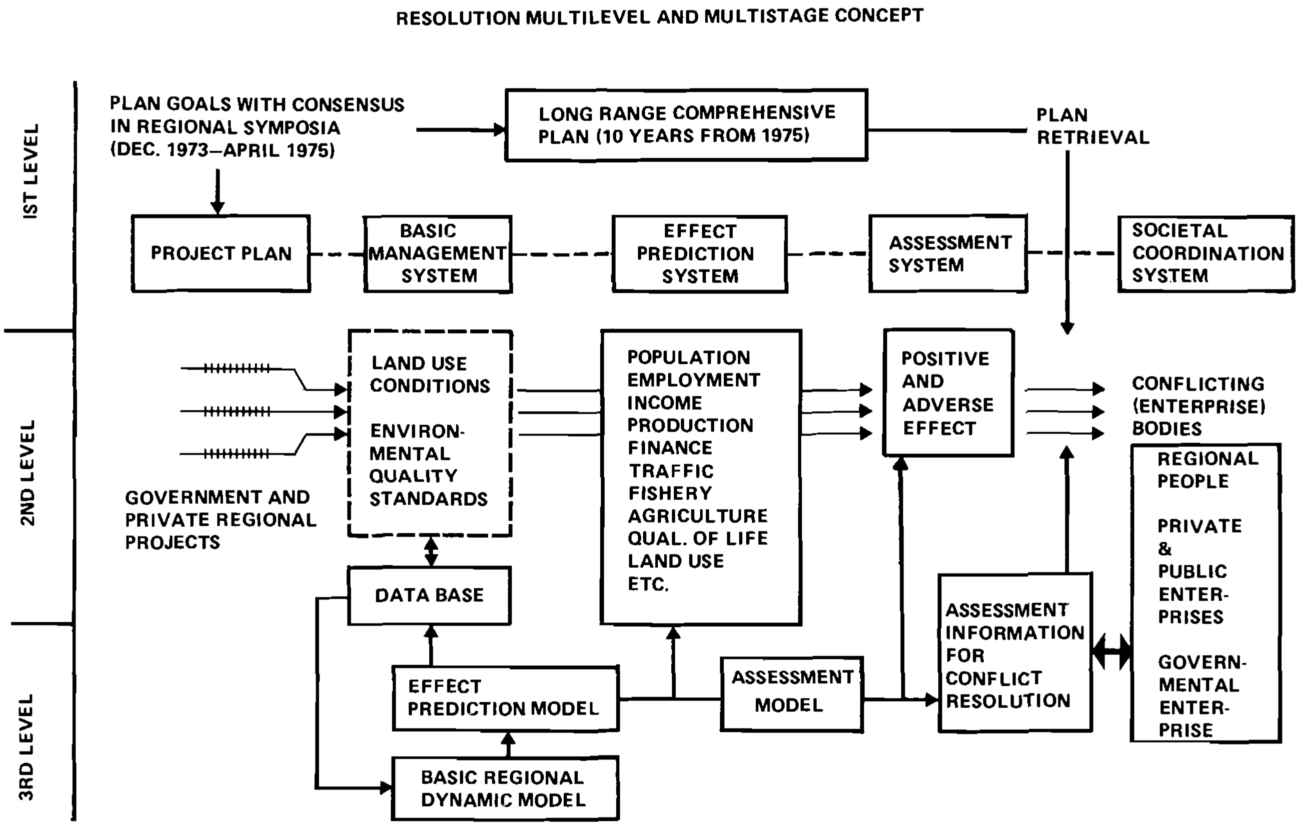


Figure 5. A comprehensive regional management system for societal conflict.

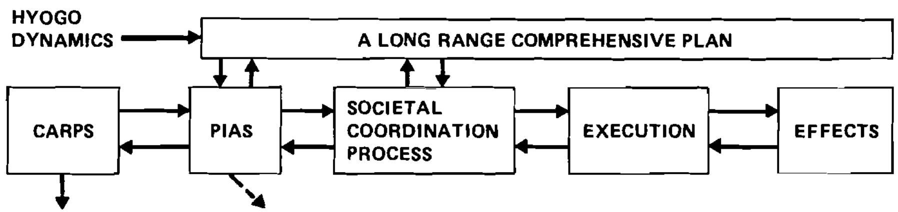


Figure 6. Regional management system.

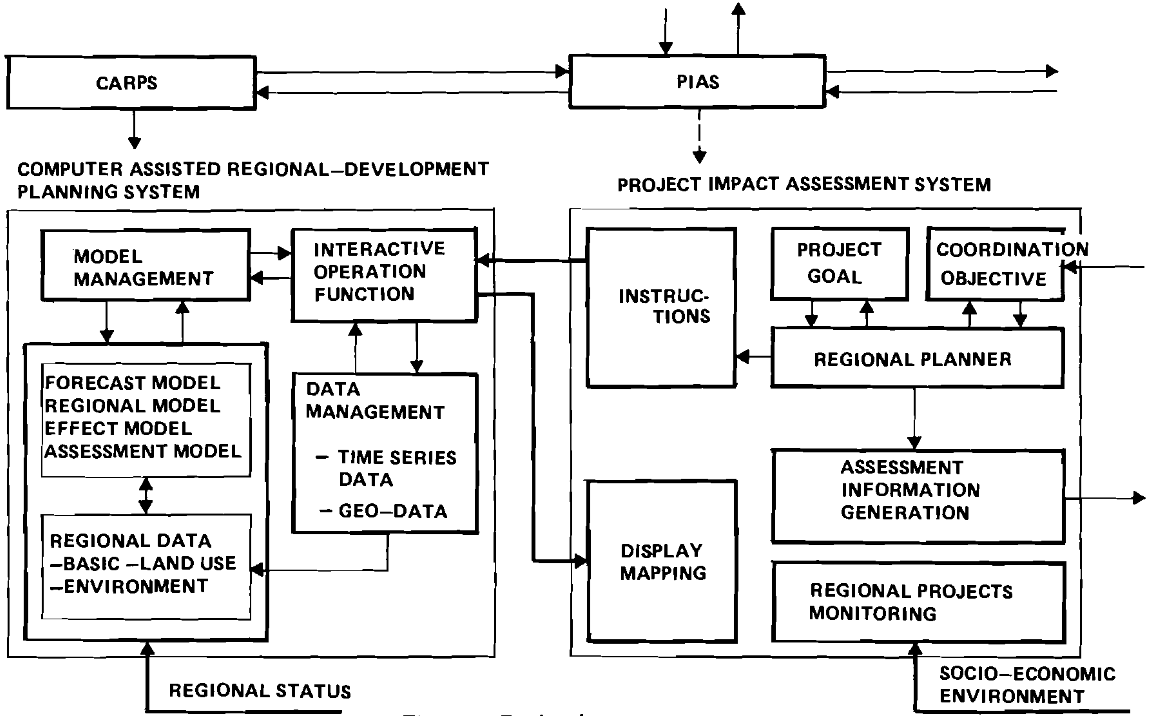


Figure 7. Regional management system.

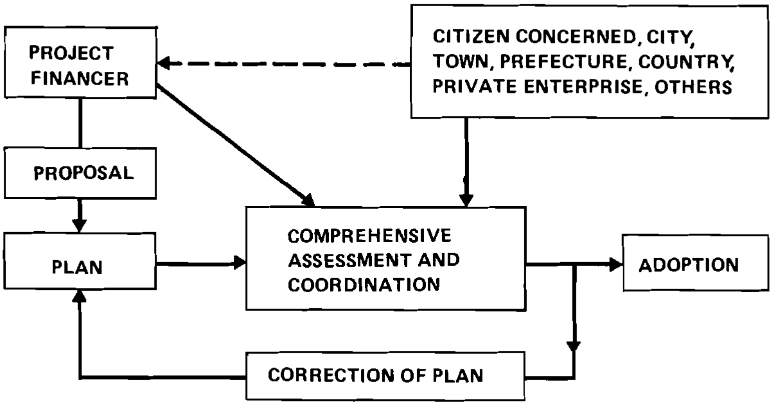


Figure 8. Process of planning and coordination.

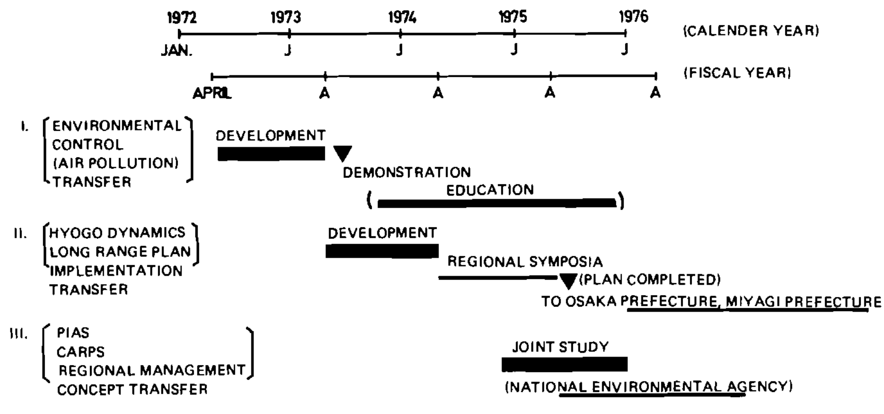


Figure 9. Historical background of planning support projects development (1972-1975).

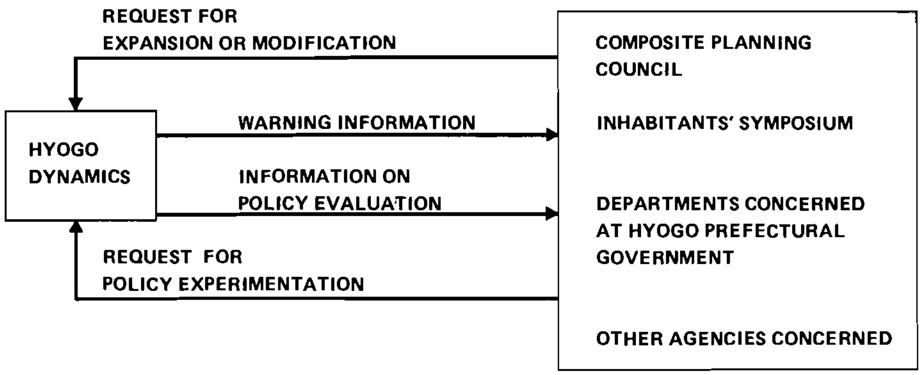


Figure 10. Roles of Hyogo dynamics in composite planning.

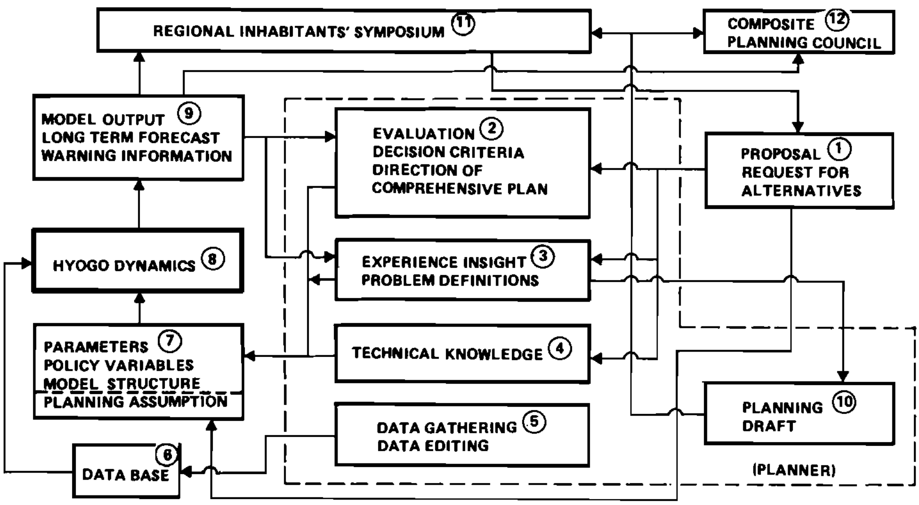


Figure 11. Long range comprehensive planning.

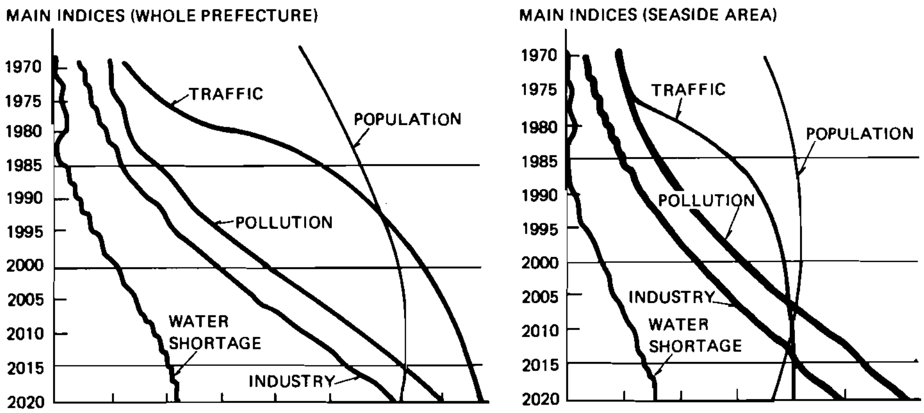


Figure 12.

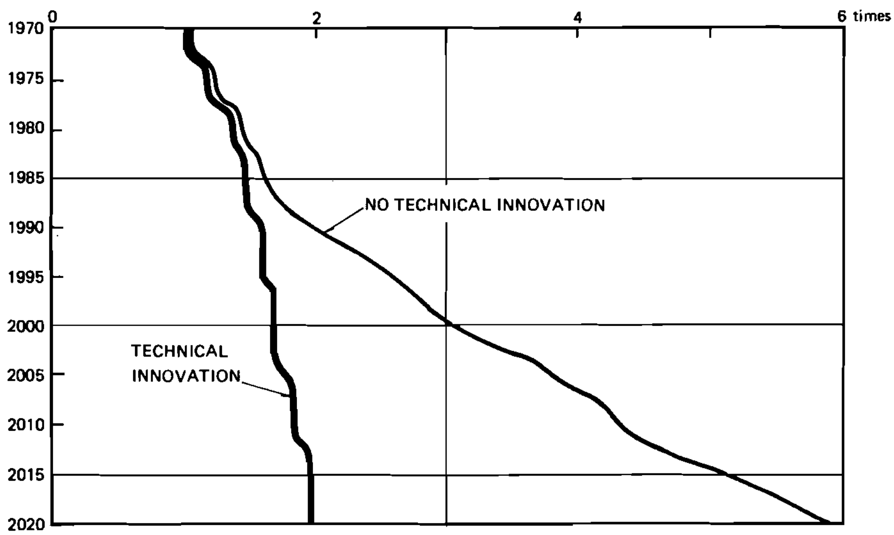


Figure 13. Air pollution (seaside area).

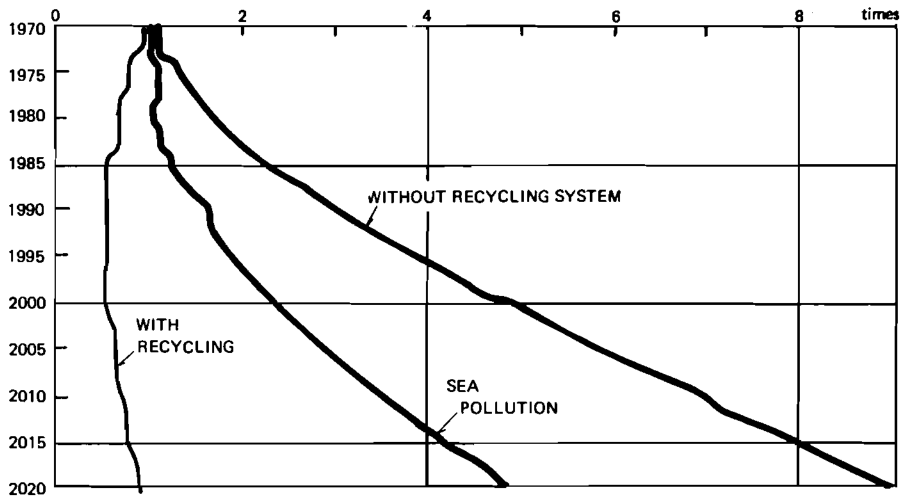


Figure 14. Water pollution (seaside area).

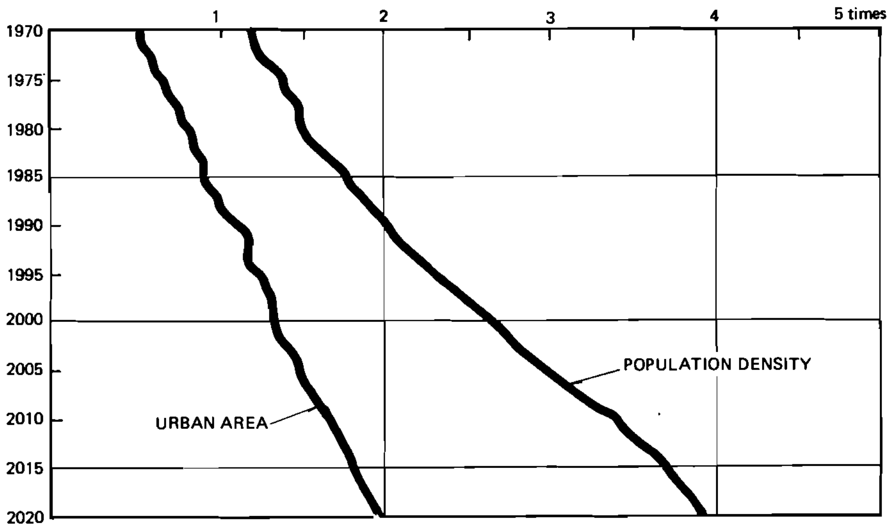


Figure 15. Urbanization (seaside area).

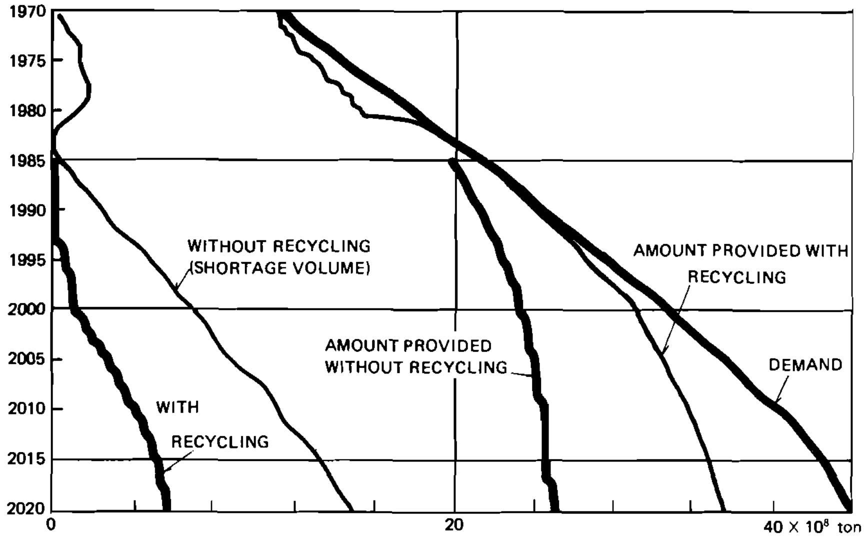


Figure 16. Water shortage (seaside area).

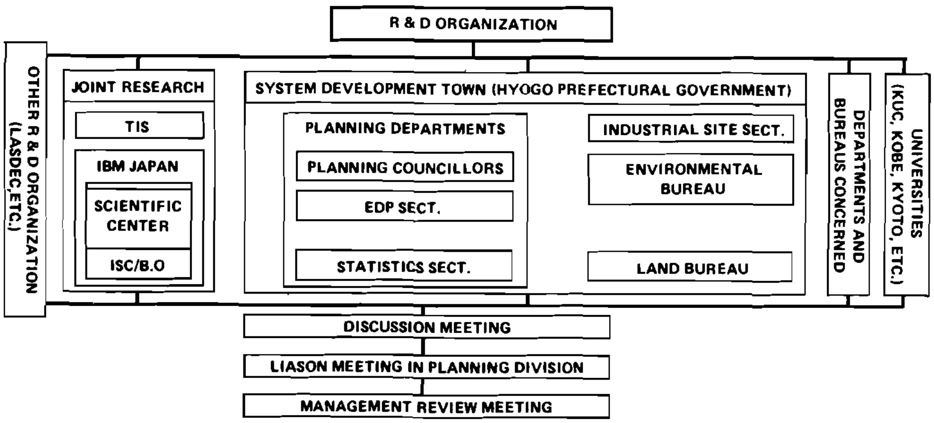


Figure 17. Organization for system development.

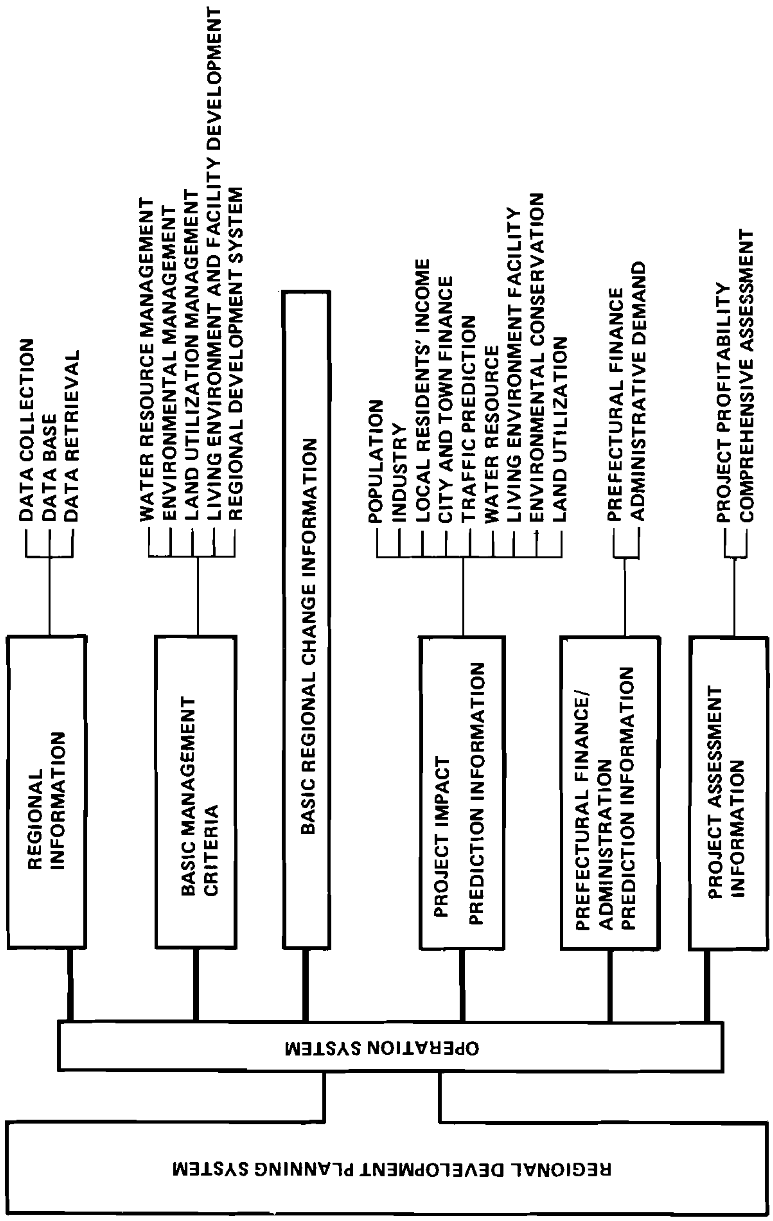
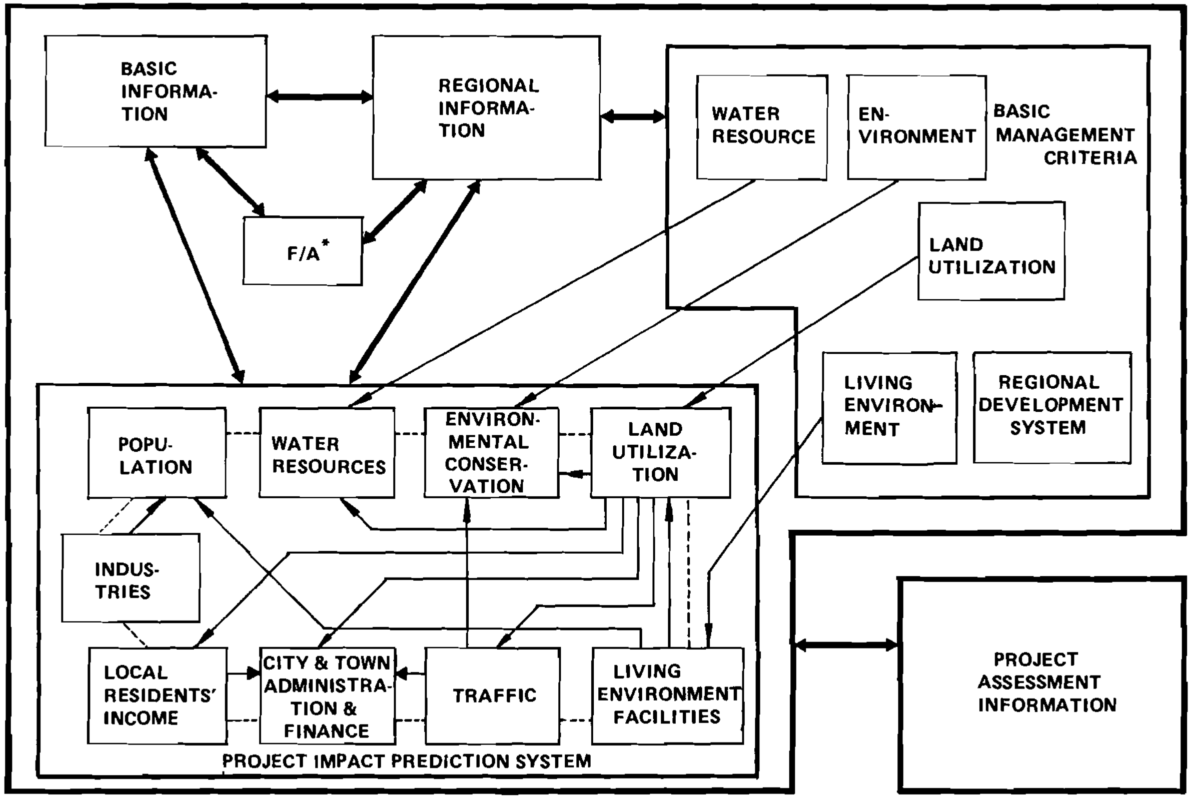


Figure 18. Structure of regional development planning system.



*F/A: FINANCE/ADMINISTRATION

Figure 19. Input and output relations.

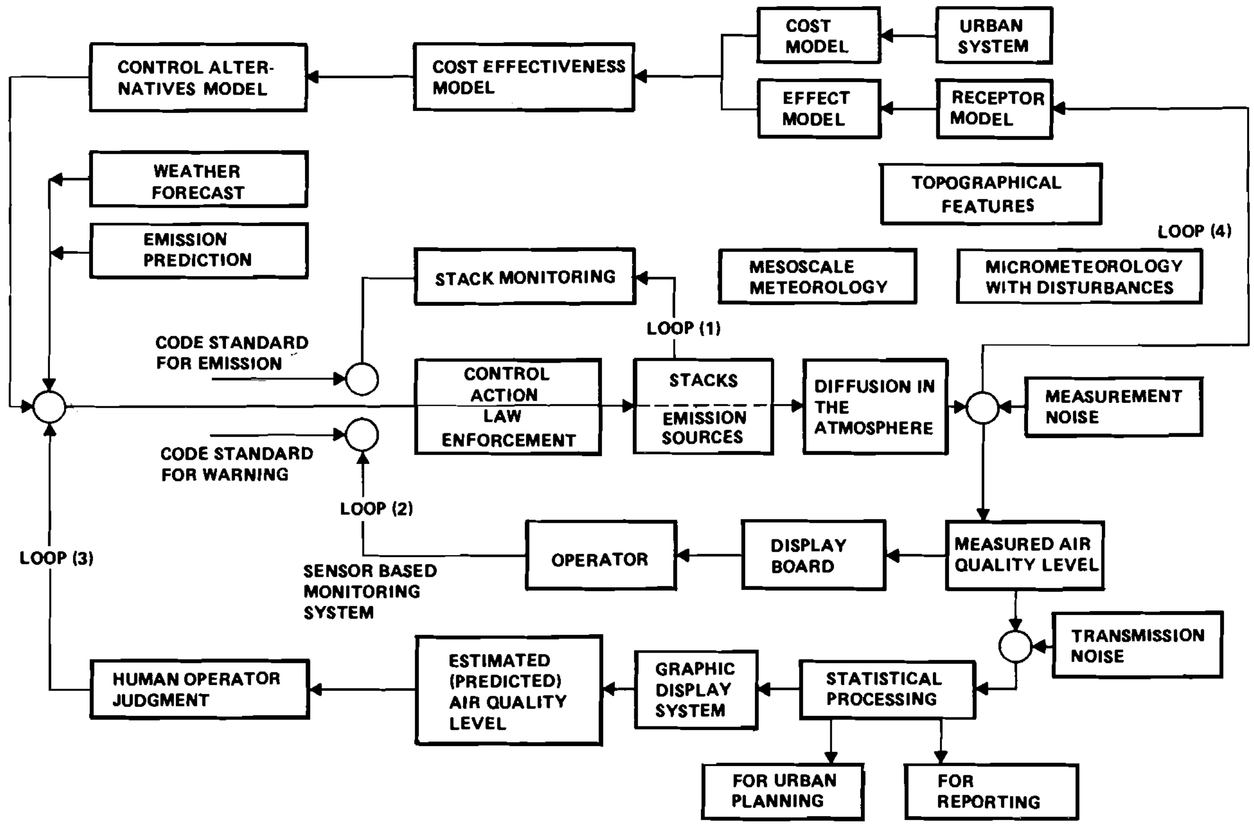


Figure 20. Conceptual flow diagram of an air pollution prediction and control system for urban environment impact assessment.

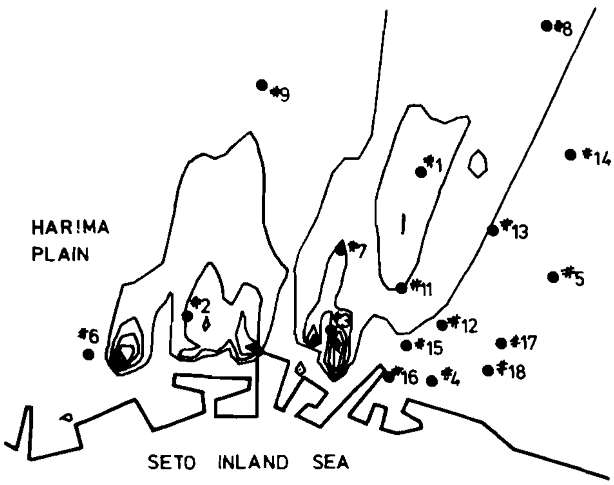


Figure 21a. Eight-hours average simulation of SO_2 concentration on May 18, 1972.

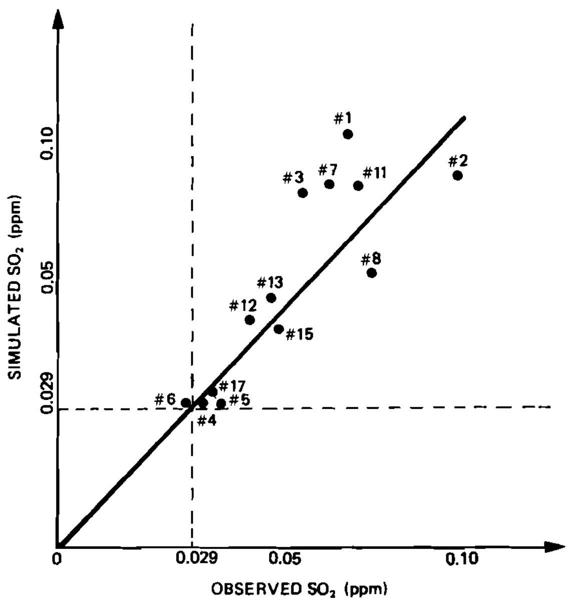


Figure 21b. Comparison between eight-hour average simulated concentration and observation stations on May 18, 1972.

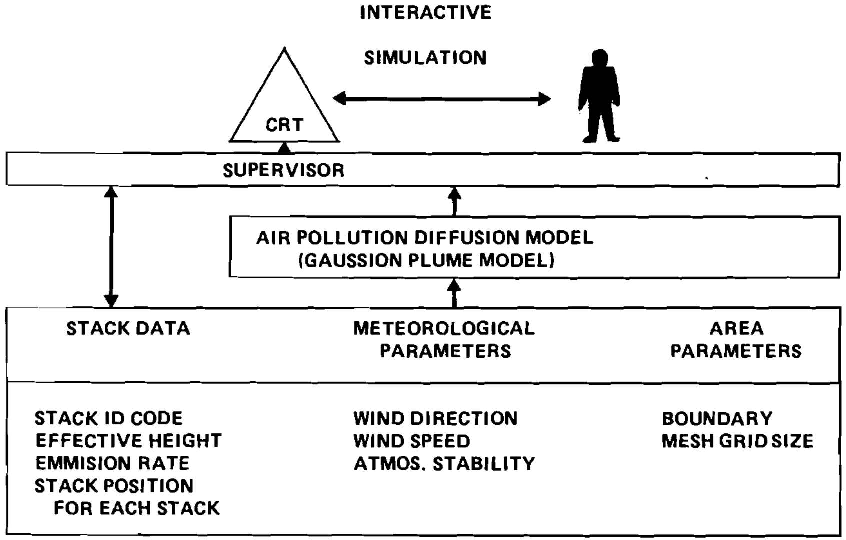


Figure 22. Overview of ISSAP interactive simulation system for air pollution.

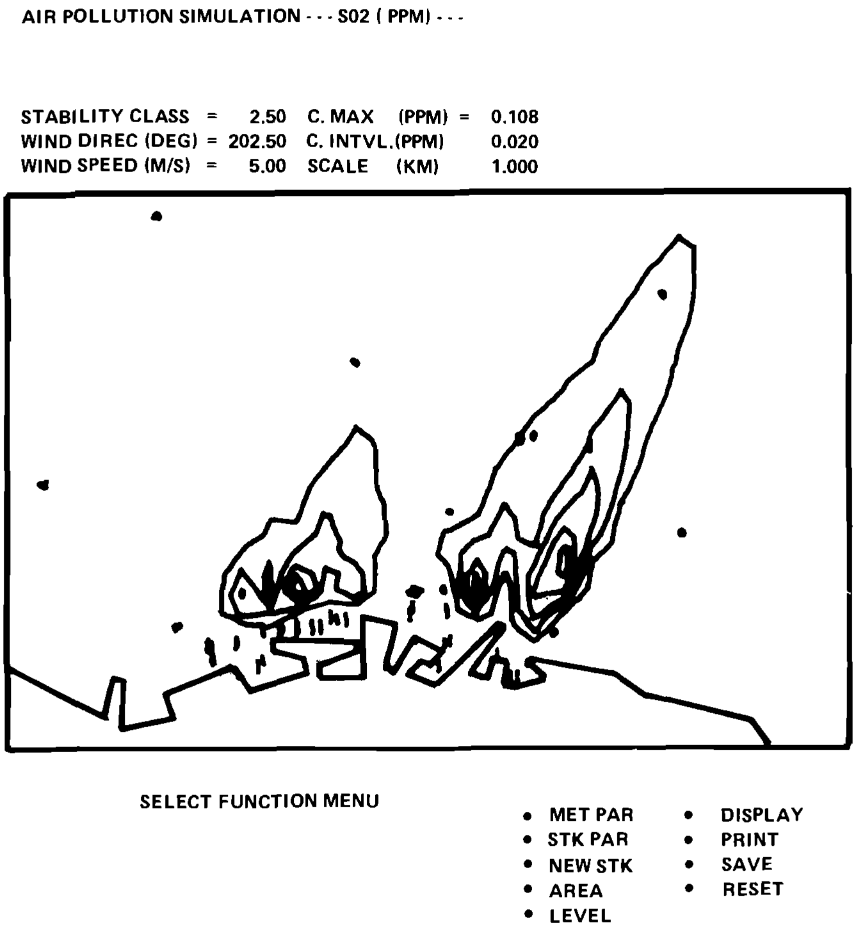


Figure 23. A typical representation on the CRT display.

A Simulation Model of Water Quality in the Kinki Region Linked with an Integrated Regional Planning Model

S. Ikeda[†], N. Adachi[†], T. Ono[††],
Y. Sawaragi[†], K. Shoji[†††], Y. Suzuki[†††], S. Tsujio[††]

SUMMARY

A simulation model of water quality was developed for the Yodo River basin, which includes Japan's biggest lake, Biwa. Lake Biwa is the origin of the main Yodo River and supplies drinking water to 12 million people and industrial water to the economic center of mid-Japan. The recent eutrophication of the lake has been bringing about serious environmental problems (conflicts between development and natural protection, between upper and lower regions for the utilization of water resources, etc.). The lake is divided into two parts geographically and two layers along the depth. Major nutrients are nitrogen and phosphorous. The aquatic ecosystem as well as water quality is modeled. Species considered are phyto- and zooplanktons, and their seasonal variations are also modeled.

The river is divided into several reaches and their water quality is modeled in connection with the environmental sector which specifies the pollution load of each divided Integrated Regional Development Planning (IRDP) area. The socio-economic feature of the river basin has a significant impact on the water quality. The future features of water quality in the Kinki region are projected by using an integrated regional planning model that is developed to find the optimum regional allocation of population and industry under the constraints such as limited usable land and water resource for the forthcoming 30 years.

[†]Kyoto University

[††]Osaka Prefecture University

[†††]Osaka University

INTRODUCTION

This research work is concerned with problem-oriented regional planning in the Kinki region linked with an Integrated Regional Planning Model that asks for a desirable socio-economic development pattern and strategies to realize it under various natural and environmental restrictions. Our macro socio-economic model is a new type of integrated regional planning model in which various aspects that are usually outside of economics such as environmental pollution, the shortage of water resources, and available land are considered explicitly within the prefecture base (Suzuki, et al., 1976).

However, this model can provide only the macro guidelines or strategies for the future state of each prefecture in the Kinki region. Even if various natural or environmental constraints are taken into consideration, it is rather difficult to carry into the macro model specific characteristics of each prefecture such as a geographical and historical situation (water rights, commonland, political or social climate, etc.), natural climate and so on. In order to examine the reality of the guideline provided by the macro model, it is essentially useful to take a problem-oriented approach for regional development planning, because we can easily bring various characteristics mentioned above into models for specific problems. As described in Suzuki et al. (1976), in the Kinki region water and energy resources are most important and serve limiting factors for a stable and desirable regional development.

The demand of water for city and industrial use is greatly increasing year by year so that the water quality becomes worse owing to both the decrease of maintaining river water and the increase of various pollutants. This fact results in serious trade-off problems.

Thus, for further discussion of the reality of regional planning, we need a hierarchical consideration as shown in Figure 1. First, various macro guidelines are derived from the upper socio-economic model based on the hypothetical external conditions. Next, macro data allocated to each prefecture is broken down according to the topographical and demographical characteristics of the Lake Biwa-Yodo River basin. Third, the obtained detailed data is provided for the water quality model examining the future water quality in Lake Biwa-Yodo River system based on the dynamic considerations of ecological and geographical features of the river basin. Finally, by returning these estimated results of water quality to the upper socio-economic model, and by feedback of the actual environmental state of the subregions to the upper models, we can integrate the regional planning models from the hierarchical point of view.

The simulation model of water quality is consistent with the two parts. One is the regional pollution emission model and the other is the dynamic water quality model for Lake Biwa-Yodo River.

The first model, which is the regional emission model, is a simple model for calculating from the given macro data the total emission of pollution, such as BOD, nitrogen and phosphorous, into the Lake Biwa-Yodo River system (from the population, industrial production, agricultural production, etc. for each prefecture). The second model is the main part of this research work and, in particular, considerable emphasis is given to the dynamic behavior of the nutrients cycle in connection with the mechanism of algea blooms in Lake Biwa, because the recent tendency of the entrophication in the lake is now heading in a dangerous direction.

The Yodo River is divided into several research areas and their water quality is modeled by using the usual Streeter-Phelps model combined with the regional pollution emission model which specifies the pollution load of each divided subregion area. Thus, the feature of water quality in Lake Biwa-Yodo River system is projected by integrating the hierarchical regional planning models for the forthcoming years.

WATER QUALITY MODEL OF LAKE BIWA-YODO RIVER SYSTEM

Brief Introduction of Lake Biwa

Lake Biwa is the largest lake in Japan, 680 km^2 in area and 27.5 × $x km^3$ in volume. Several million years ago, this lake was formed by a diastrophism and thought to be as old as lakes like Baikal and Lake Tanganyika. It is located in the upper reaches of the Yodo River and is the most important source of water for the main part in the Kinki region, Kyoto-Osaka-Kobe, one of the most densely populated and industrialized areas in Japan. This lake is composed of two parts; the northern part is the main-lacustrine basin and still remains at an oligotrophic stage. The southern part, smaller and shallow sublacustrine basin, is called the Southern Lake. The lake water flows in from more than 100 rivers but has only one outlet situated at the end of the Southern Lake and flows downstream to the Yodo River (see Figure 2).

The general characteristics of Lake Biwa are shown in Table 1. In the Northern Lake, three horizontal currents are observed as illustrated in Figure 5 below. A considerably large change is observed in flow and position of currents, but the current speed is said to be about 10 cm/s.

As for the water quality of Lake Biwa, much research and experimental work has been done (see Japan Society, 1970-1971; Lake Biwa Office, 1974). Nitrogen and phosphorous indicate the progression of eutrophication in the lake. A part of the results of the work is shown in Figure 3. Total nitrogen (N) and phosphorous (P) loading per unit lake surface and plotted for vertical axis and the mean-water depth is plotted for horizontal axis. Figure 3 shows that the Northern Lake is in a critical transition state from oligotrophic to eutrophic. In the Southern Lake, the amounts of N and P have already exceeded the eutrophication standard. The great amount of pollution in the Southern Lake will be described by the observed number of phytoplankton at the shore of Otsu city, where the city water for Kyoto area is taken in (see Figure 4). The algea bloom in 1969 damaged the lake's ecosystem and also caused a mildew odor for city water.

Eutrophication Model of Lake Biwa

Division of the Region

The volume of the Northern Lake is 27.4 km^3 and the area is 610 km^2; the Southern Lake is 0.16 km^3 and 70 km^2, respectively. Since the Northern Lake is much larger than the Southern Lake, we divide the Northern Lake into two parts, as shown in Figure 5. River Ado-Hikone city line is the boundary between the first and the second lake currents.

In the Southern Lake, which is very shallow, the thermocline does not appear. There is a difference of only about 1^0 C in the water temperature between the surface and the bottom. Therefore we assume that the water quality of the Southern Lake can be represented by a perfectly mixed compartment.

Further, it is necessary to divide the Northern Lake into two layers in a horizontal direction because the lake's geophysical conditions between the upper and lower water are very different. It is well known that a complete horizontal circulation exists from February to March (see Japan Society, 1970-1971). In April, the thermal stratification begins to form and it develops to the maximum from June to August, when the thermocline stays at the depth of about 15 m. The thermocline prohibits the mixture of the water between the warm upper layer and the cold lower layer. In October, it goes down to 20 m and in November, 25 m. Again, a complete circulation is observed (see Figure 6). In this paper, the thermocline is assumed to be located at 18 m depth and the rate of circulation between the two layers is varied in a year as shown in Figure 7.

As a result, Lake Biwa is divided into five compartments as illustrated in Figure 8, and in each block the temperature and the quality of the water are assumed to be uniform. In addition, we assume that the water flows one way from compartment I to compartment III and from III to V. It is also assumed that there are no flows between compartment II and IV. After the phytoplankton and the zooplankton in an upper layer have died, some of them go down to the lower layer. Hence, a sinking rate for the plankton is also given.

Nutrients Cycle

Nitrogen and phosphorous are considered to be the major nutrients in the lake. The outline of these nutrients in the lake is illustrated in Figure 9. The nitrogen is divided into organic and inorganic forms. The latter consists of ammonia nitrogen (NH_4-N), nitrite nitrogen (NO_2-N) and nitrate nitrogen (NO_3-N). The phosphorous also has the organic and inorganic forms which are almost of the type of PO_4-P. The ammonia and the nitrate nitrogen and inorganic phosphorous are the nutrients for the phytoplankton. And the phytoplankton is grazed by the zooplankton. The death of the zooplankton, its excretion of the prey, the respiration of phytoplankton and their death regenerate the organic nitrogen. The organic nitrogen and phosphorous are decomposed into the inorganic forms by various bacteria. Thus, a total nutrient cycle contributes to the primary production in a lake ecosystem, as completed in Figure 9, if there are no external inflow and outflow (see Ikeda and Adachi, 1976).

Simplified Model of the Nutrient Cycle

For the sake of simplicity, we examine the inorganic nitrogen and the total phosphorous. Then, we have the following simplified scheme of the nutrient cycle (see Figure 10). The average ratio of phosphorous and nitrogen in the plankton is given as follows (see Lake Biwa Office, 1974):

$$P : N = 1 : 10 \quad .$$

The dynamic representation of the system in a block can be derived from the mass balance equation, taking account of mass transportation (see Thomann et al., 1970; and Ikeda et al., April 1976):

$$\frac{dN_o}{dt} = -K N_o + D_p P_n + D_z Z_n - G_z Z_n + q(S_1 - N_o)$$

$$\frac{dN_i}{dt} = K N_o - G_p P_n + q(S_2 - N_i)$$

$$\frac{dP_n}{dt} = (G_z - D_z) P_n + q(S_p - P_n)$$

$$\frac{dZ_n}{dt} = (G_z - D_z) Z_n + q(S_z - Z_n)$$

$$\frac{dP_h}{dt} = \{(D_p - G_p) P_n + (D_z - G_z) Z_n\}\theta + q(S_3 - P_h) \quad .$$

Definitions of symbols and variables in these equations are as follows:

N_o : organic nitrogen concentration (mg/liter);

N_i : inorganic nitrogen concentration (mg/liter);

P_n : biomass of phytoplankton measured by its nitrogen concentration (mg/liter);

Z_n : biomass of zooplankton (mg/liter);

P_h : phosphorous concentration (mg/liter);

K : rate of conversion from N_o to N_i (per day);

S_1, S_2, S_3 : influent concentration of organic nitrogen, inorganic nitrogen, and phosphorous, respectively;

S_p, S_z : influent concentration of phyto- or zooplankton;

G_z : growth rate of zooplankton;

G_p : growth rate of phytoplankton;

D_p, D_z : death rate of phyto- and zooplankton, respectively;

q : flow rate;

θ : average ratio of nitrogen and phosphorous in plankton (P_h/N) .

Growth and death rates used in this model have some nonlinear functions which play important roles in the dynamic behavior of planktons.

The detailed description of growth or death rates are as follows:

$$G_p = \mu(I, T)\{(P_h/(K_p + P_h)) \ (N_i/(K_n + N_i)\}$$

$$G_z = \beta\{P_n/(K_z + P_n)\}$$

$$D_p = D_pT + \alpha Z_n, \ D_z = K_tT + K_o, \ (D_p, K_t, K_o = \text{constants})$$

where $\mu(I, T)$ is a saturated photosynthesis rate of phytoplankton. A possible expression of μ is the following (see Di Toro et al., 1971):

$$\mu(I, T) = \frac{K\ efT}{K_e H} \left(e^{-\alpha'} - e^{-\alpha''}\right)$$

$$\alpha' = (I/I_s)\ \exp(-K_e H),\ \alpha'' = (I/I_s)$$

where

e = natural logarithm constant;

K_p, K_n, K_z = Michaelis constants;

f = photo-period;

I = light intensity at the surface;

I_s = the light saturation intensity for photosynthesis;

K_e = extinction coefficient;

H = water depth;

T = water temperature.

More refined functions are also available for the saturated photosynthesis rate. Since these equations have five variables in each compartment, the whole dynamic of the nutrients' cycle is represented by a system of differential equations with 25 variables.

Observed Data of Phytoplankton

The number of phytoplankton (number) in the Southern Lake was measured every day at Keage Filtration Plant which is located at Kyoto (see Water Service Bureau, 1974). As illustrated in Figure 11, in 1974 the number of plankton increased greatly from March to June. The value of the peak is about 2000~4000 cells/ml which corresponds to 0.3~0.5 mg-N/liter converted to nitrogen, where the conversion rate is quoted from Di Toro et al. (1971). And the population of the phytoplankton oscillates during the spring time. This may be caused by the fact that the species of the plankton change and there are some patches of the phytoplankton distribution in the lake's water. The population of phytoplankton decreases in July and increases a little in September, August, and October.

In the Northern Lake we have no continuous observation of phytoplankton, but owing to the report (Lake Biwa Office, 1974) it appears that the population of phytoplankton increases in April, May, and August.

Parameters in the Model

Parameters used by Di Toro et al. (1974) are adopted tentatively and are adjusted to fit the observed features in each block together with some additional unknown parameters. The typical seasonal variations of water temperature and light intensity are used in the simulations of the model. In this model the water level is assumed to be constant. This means that the total amount of water which flows into the lake is equal to the amount flowing out from the lake.

Thus, by means of trial and error or by sensitivity analysis through many computer simulations, the various parameters in the model are determined so as to meet the required trend of seasonal variation that corresponds to the observed data displayed in Figure 11. One of the typical simulation examples is shown in Figure 12 (see Ikeda et al., April 1976).

Water Quality Model of the Yodo River

This model roughly estimates water quality of the Yodo River when pollution loads to the river basin are given. The Yodo River and its branches are divided into five reaches as shown in Figure 13. Some characteristics of each block are shown in Table 2. The monthly variations of water quality of the river are concerned with the purpose of the overall model. However, the detention times in each block are relatively small as shown in Table 2. Therefore, a static model is supposed to be sufficient. A simple dynamic model of water quality is represented by a Streeter and Phelps' equation. A discretized form of this equation is the following:

$$Z_i(k+1) = (1 - \alpha_i)Z_i(k) + \frac{Q_{i-1}(k)}{V_i}Z_{i-1}(k) - \frac{Q_i(k)}{V_i}Z_i(k) + \frac{m_i(k)s_i(k)}{V_i}$$

where

$Z_i(k)$: BOD concentration in the i-th block at $t = k\Delta t$;

$Q_i(k)$: flow rate in the i-th block;

$m_i(k)$: rate of runoff and effluent introduced in the i-th block;

$s_i(k)$: BOD concentration of runoff and effluent;

V_i : volume of water in the i-th block;

α_i : decay rate of BOD in the i-th block.

The equation also can be derived from BOD balance equation in a compartment shown in Figure 14. If stationality of the model is assumed; $z_i(k + 1) = z_i(k)$ (k=0, 1,...)

$$z_i = \frac{Q_{i-1}z_{i-1}+m_i s_i}{Q_i + \alpha_i V_i} \quad .$$

For nitrogen and phosphorous, we assume similar equations of mass balances. Parameters Q_i and V_i in each block are those averaged during a month, and they are determined from the observed data. The parameters α_i, which represent various reactions of pollution materials in each block, are determined by the least squares method with the observed data of water quality in a specific year. Figure 15 illustrates one of the predicted results of water quality at Hirakata point (upper part of Osaka), which was calculated on the basis of the data from April 1966 to March 1967. In estimating water quality in the future, these parameters are held unchanged, and only changes of pollution loads are taken into consideration. Therefore, it must be stated that the simulated results do not estimate future water quality in the strict sense, but only give a kind of index of the quality of water.

Integration of the Two Submodels

The two submodels above must be integrated into one unified model. This integration is not difficult since the two submodels are related sequentially. The water quality of the Southern Lake is derived by the eutrophication model described above. Given outflow of the water from the Southern Lake into the Uji River the water quality model will give the estimate of the concentrations of pollution material in each reach sequentially. The only difficult problem is how to estimate BOD inflow into the Uji River from the Southern Lake since BOD concentration is not considered explicitly in the eutrophication model. A possible way to understand the problem is to assume that BOD concentration is proportional to organic material in the lake.

REGIONAL POLLUTION EMISSION MODEL

A regional pollution emission model has been built to assess environmental impacts of alternative regional development plans determined by the main IRDP model for the Kinki Area. This model is composed of three environmental submodels, namely, air and water pollution submodels and a submodel for solid water.

In this section, we briefly explain a submodel for the water pollution that calculates pollution loads (BOD value is adopted as a standard to express the water quality) of the river basin getting fundamental data of pollution sources from the main IRP model. Furthermore the load of nutrients (mainly nitrogen and phosphorous) is also calculated by this model to investigate the eutrophication phenomenon in Lake Biwa.

The conceptual structure of this model is shown in Figure 16 showing major component parts of the model. Definitions of the terms in the figure are listed directly below as they represent the data needs of the model:

X_Y : pollution sources;

Z : amounts of pollutants generated by source;

α_i : primary generation factor of pollutant;

K : treatment ratio of pollutant;

θ_i : coefficient of pollution control effect;

ω_i : rate of runoff.

Water pollution sources are classified into two categories:

- artificial pollution sources, and
- natural pollution sources.

As artificial pollution sources, sectors such as residents, industries, livestock, and agriculture are considered in this model.

The runoff from forest and midland and rainfall are taken into account as natural pollution sources. The natural pollution load is of course, originally from the artificial sources in Japan. No pollution load of BOD is considered for natural pollution sources, because runoffs of BOD from forest and rainfall are negligible.

Pollution loads for each divided reach as shown in Figure 13 are calculated from the monthly input data to each sector in Figure 16. These input data are provided from the upper socioeconomic model, and the obtained results for each reach shall again be used as the input data of the water quality models.

In this model, the primary generation factors α_i are considered to play important roles as key parameters. Treatment ratio K and pollution control effects θ_i are policy parameters. Primary estimated values of α_i are given in Table 3.

PRELIMINARY SIMULATION EXAMPLE

In order to examine the availability of our water quality model in the Kinki area, a preliminary case study was carried out corresponding to the obtained results of Case 1 in the upper model (see Suzuki et al., 1976), which is considered to be one of the most probable growth rate patterns on the future Japanese economy:

- GNP growth rate: 5%;

- Population growth rate: 0.8% .

Figures 17 and 18 illustrate the estimated total BOD and nitrogen concentrations at Hirakata-point, upper reach of the Osaka prefecture in 1995. In this tentative calculation, it is assumed that in the sewage treatment technology the 1965 level will be improved twice as much by 1995. Nevertheless, we will have double the amount of pollution in the water at the upper reach of Osaka prefecture.

SOME REMARKS FOR FURTHER RESEARCH

As a task of the research project on Integrated Regional Development Planning (IRDP) for the Kinki area a simulation model of water quality has been developed to examine the feasibility of alternative regional development plans from the standpoint of water quality management.

Since this research project is now in progress, we have not been able to give the integrated results linked with the upper IRDP model. However, at the final stage, we could have combined the macro regional planning model with the problem-oriented regional models, such as our water quality model, and integrated these models from the hierarchical point of view.

References

Di Toro, D.M., et al. (1971), *A Dynamic Model of Phytoplankton Population in Sacramento-San Joaquin Delta*, Advances in Chemistry Series, No. 106, American Chemical Society, Washington, D.C.

Ikeda, S., T. Ohtsuki, and Y. Sawaraki (1976), *A Simulation Model of Heutrophication in Lake Biwa*, research report of special research program on Detection and Control of Environment Pollution sponsored by the Ministry of Education, Japan.

Ikeda, S., and N. Adachi, Dynamics of Nitrogen Cycle in Lake Biwa and its Stability, in *J. Ecological Modelling* 2 (1976) 213-234.

Japan Society of Civil Engineering (1970-1971), *Report on Future Water Quality of Lake Biwa*, Tokyo.

Lake Biwa Office (1974), Kinki Region Construction Bureau, *Eutrophication in Lake Biwa.*

Suzuki, Y., et al. (1976), An Integrated Regional Planning Model: A Case Study of the Kinki Area, this volume.

Thomann, R.V., et al. (1970), *Modeling of the Nitrogen and Algal Cycles in Estuaries*, 15th International Water Pollution Research Conference, San Francisco, California.

Water Service Bureau of Kyoto City (1974), *Examination of Water Quality.*

Table 1. Characteristics of Lake Biwa.

Source: [5]

Normal water level	T.P. + 84.371 m
Total acreage of the lake	680 km^2
Average depth	41.2 m
Maximum depth	103.6 m
Volume of water	27.5 km^3
Average annual precipitation	1900 mm
Average annual runoff	$53 \times 10^8 m^3$
Average monthly air temperature	3.1 ~ 26.2°C
Number of tributaries	121
Retention time	5.2 year
Ratio catchment area/lake surface	5.7
Population around the lake	95×10^4
Land usage of catchment area	
forests etc.	54.8%
Lake Biwa	17.7%
rice paddies	17.4%
others	10.1%

Table 2. Typical flow rate and its velocity.

No.	Block	Length (km)	Flow Velocity (m/s) at Sept. 1965	Flow Rate (m^3/s) at Sept. 1965
1	the lower reaches of the Yodo	16.365	1.00	206.81
2	the upper reaches of the Yodo	10.71	1.00	206.81
3	the river Kizu	16.00	0.83	25.64
4	the river Uji	36.00	0.67	127.75
5	the rivers Kamo and Katsura	5.60	0.34	25.33

Table 3.

A. Generation factor of N and P in *domestic* wastes (g/person/day).

Night soil	9.0	Nitrogen
Miscellaneous use	3.0	
Total	12.0	
Night soil	1.1	Phosphorous
Miscellaneous	0.9	
Total	2.0	

B. Generation factor of N and P in *industrial* wastes (Kg/day/unit production).

	Nitrogen	Phosphorous
Food Processing	1.53	0.1
Furniture & Fixture	0.55	0.056
Pulp & Paper	0.726	0.019
Chemical	6.423	0.358
Steel	0.206	0.004
Nonferrous Metals	0.087	0.003
Stone, Clay & Glass	0.067	0.007
Leather	8.065	0.251
Machinery	0.188	0.046

C. Generation factor of N and P in *livestock* wastes (g/head/day).

	Nitrogen	Phosphorous
Cattle	28.0	5.6
Pigs	31.3	20.5
Chickens	0.0	0.0

Table 3.
(continued)

D. Generation factor of N and P in Drainage of *agricultural land* (Kg/month/hr).

Note: Pollution load in drainage of agricultural land =

(Amount of fertilizer) × (rate of escape α_4) +

(Area of agricultural land) × (rate of existence α_5)

$$\times \frac{\text{(Amount of rainfall in each month)}}{\text{(Average annual rainfall)}}$$

		α_4	α_5
Nitrogen	Paddy field	0.10	1.728
	farms	0.30	1.941
Phosphorous	Paddy field	0.013	0.106
	farms	0.013	0.057

E. Generation factor of N and P in *forest runoff* (Kg/month/km^2)

Note: Pollution load in forest runoff

= (forest area) × (rate of escape α_6)

$$\times \frac{\text{(amount of rainfall/each month)}}{\text{(average annual rainfall)}}$$

	Aichi River	Ohtoi River
Nitrogen	57	2.7
Phosphorous	1.5	10.5

F. Generation factor of N and P in Rainfall in the Kinki region (ppm)

Nitrogen	0.20
Phosphorous	0.014

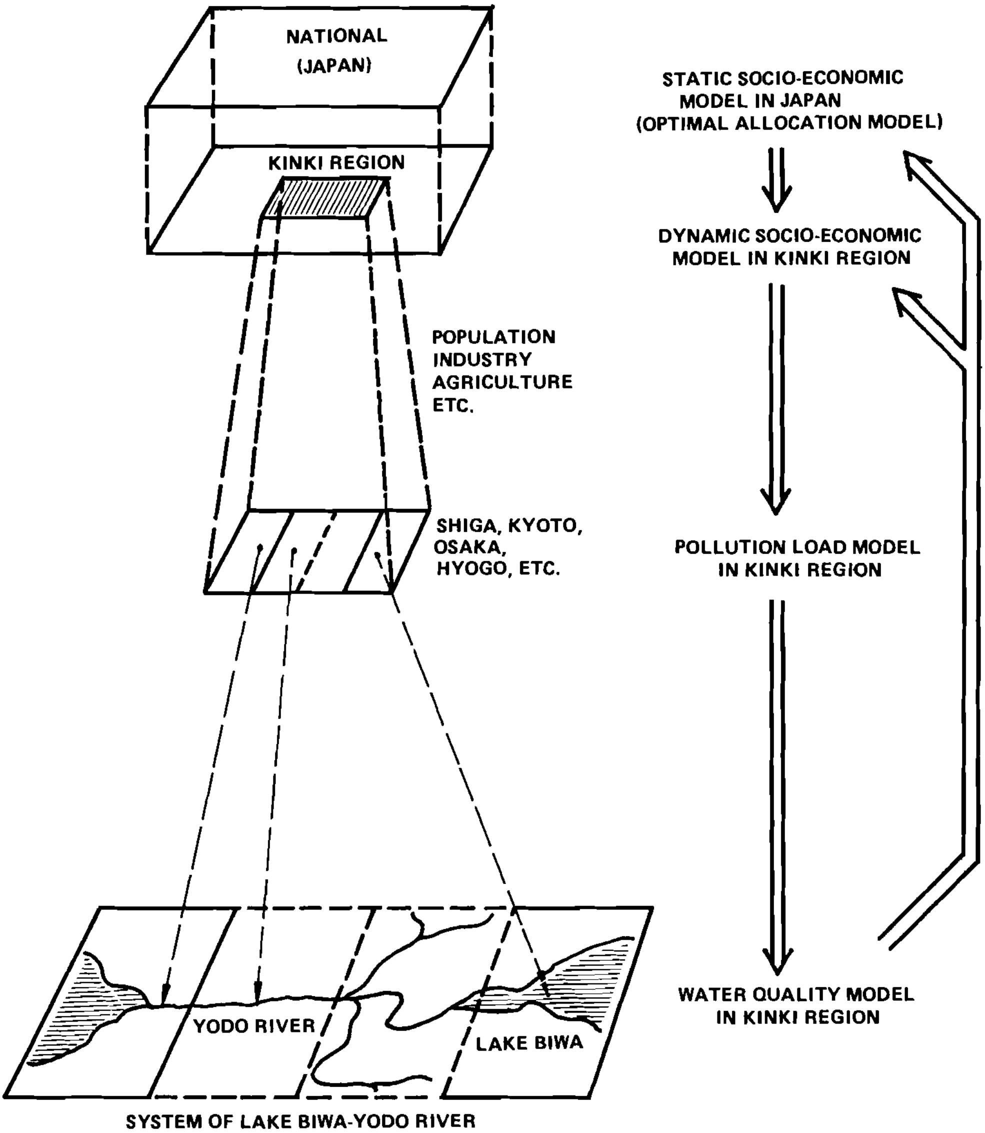


Figure 1. Hierarchical structure of each model.

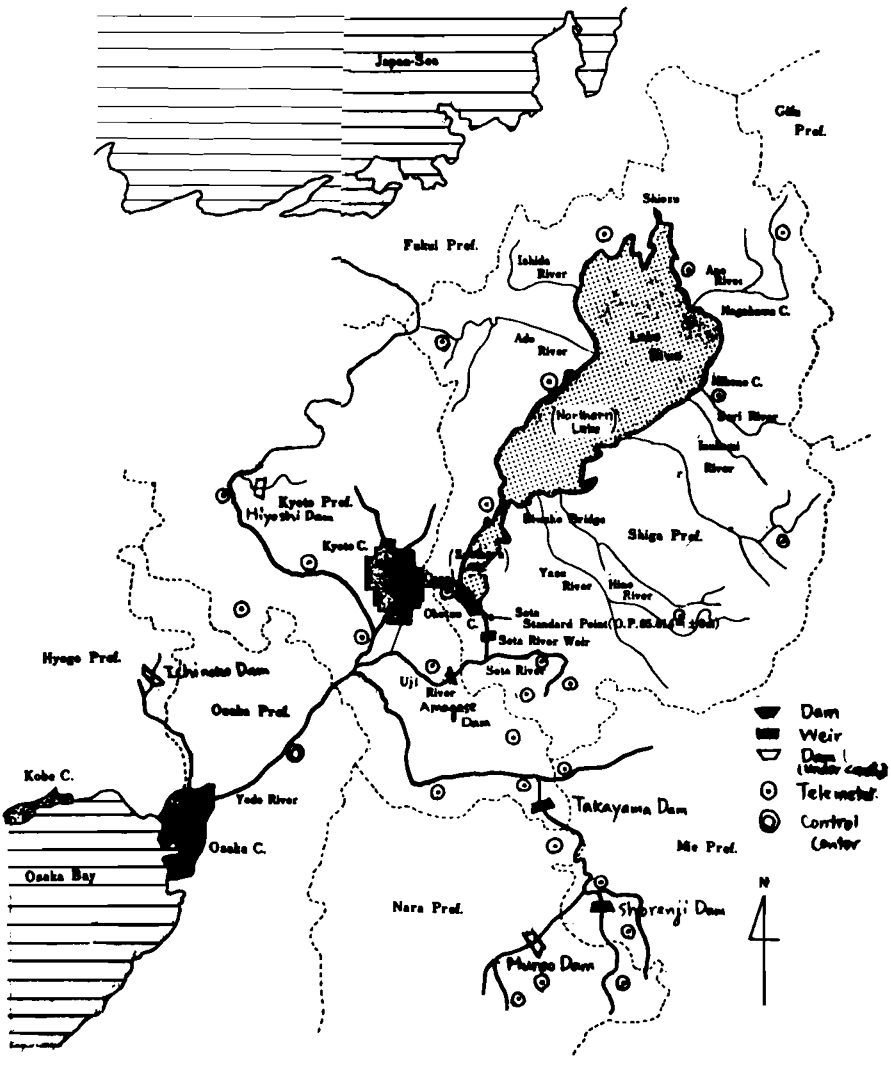


Figure 2. The Lake Biwa and Yodo River region.

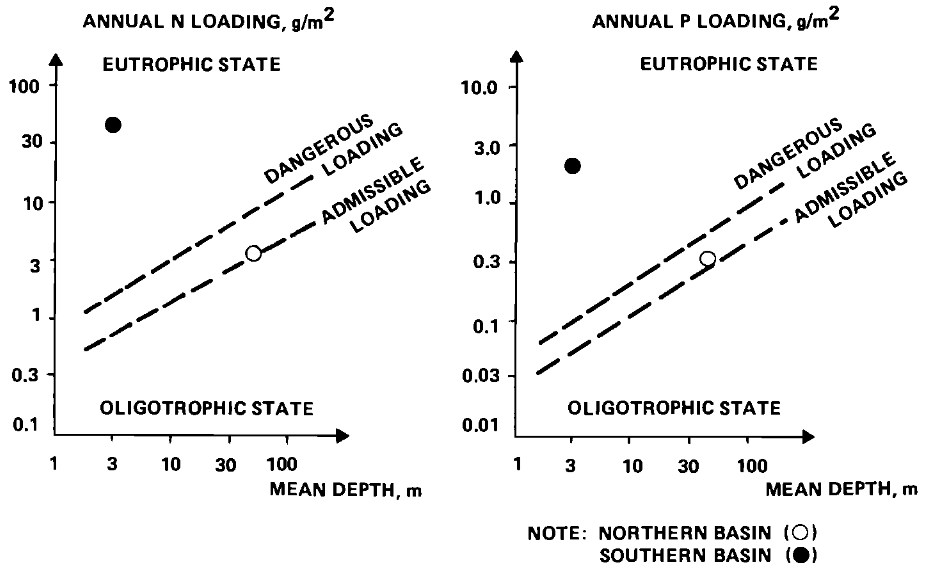


Figure 3. Loading of nitrogen and phosphorous on Lake Biwa.

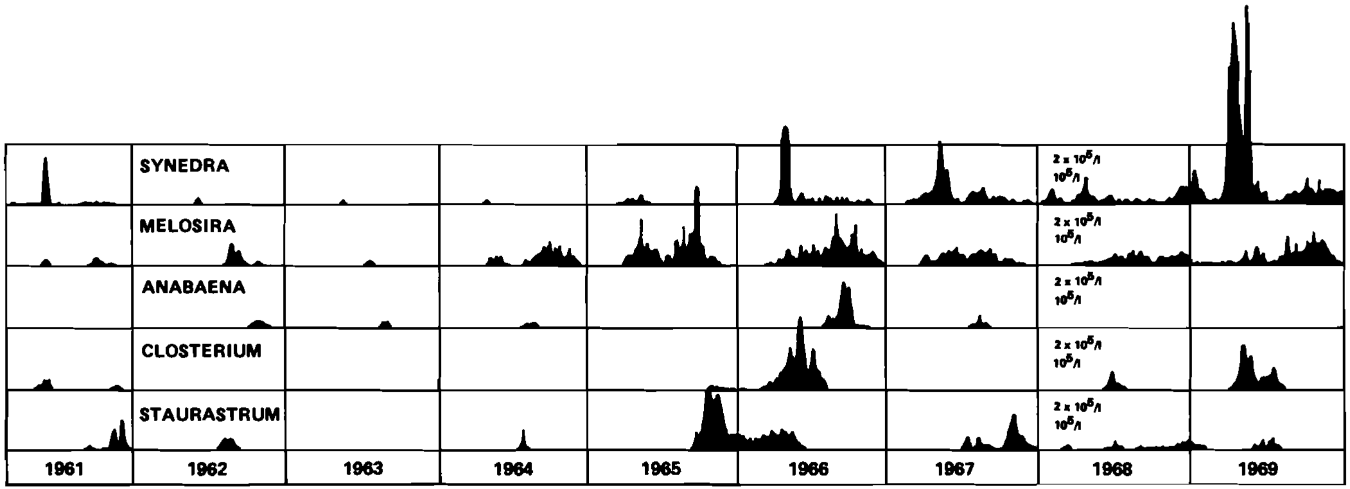


Figure 4. Variation of number of cells of dominant phytoplankters in Kyoto Sosui, located in the southern basin from 1961 to 1969.

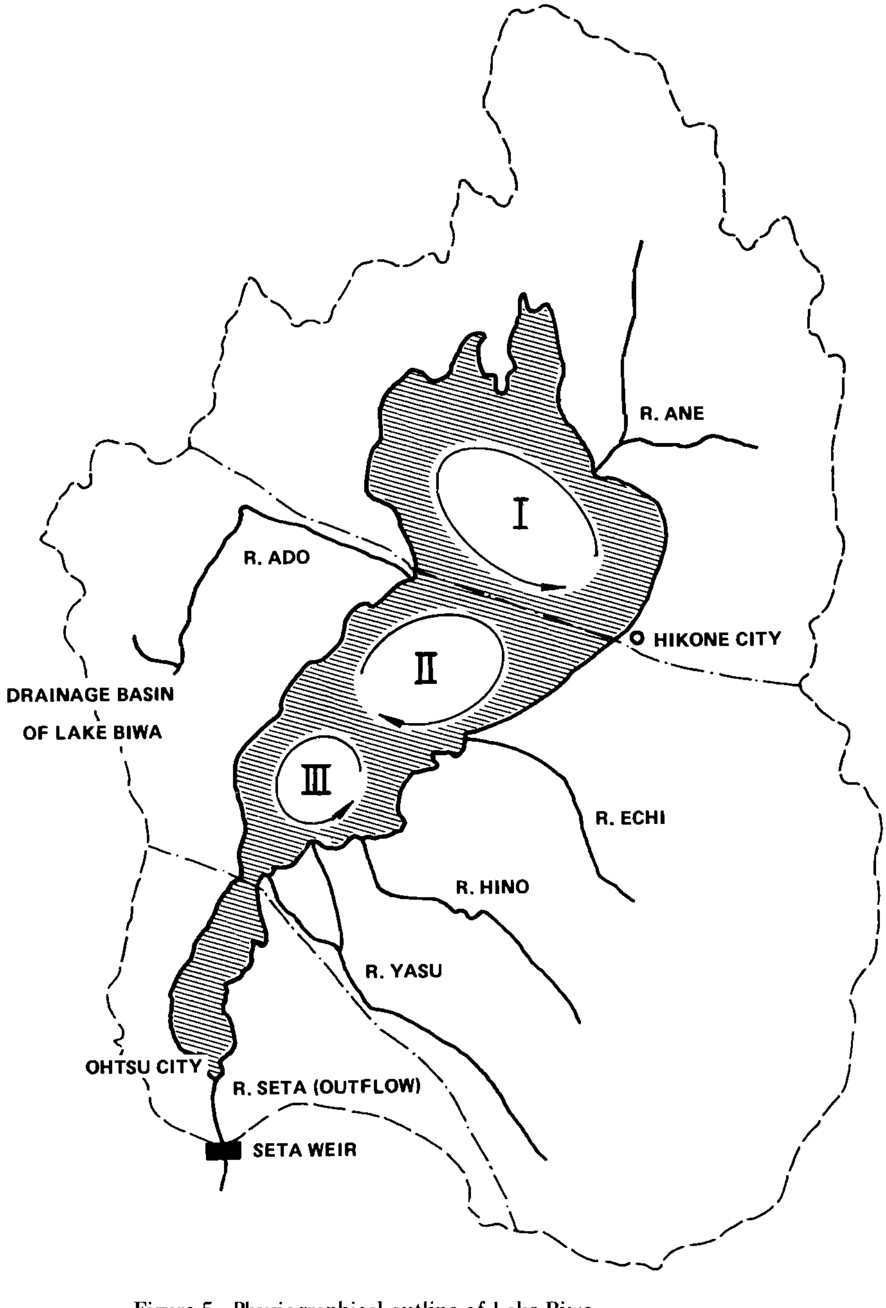


Figure 5. Physiographical outline of Lake Biwa.

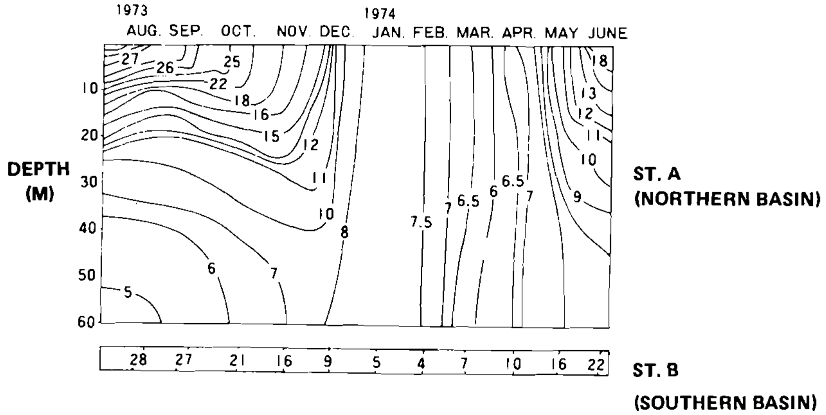


Figure 6. Monthly variation of the vertical thermal structure (°C).

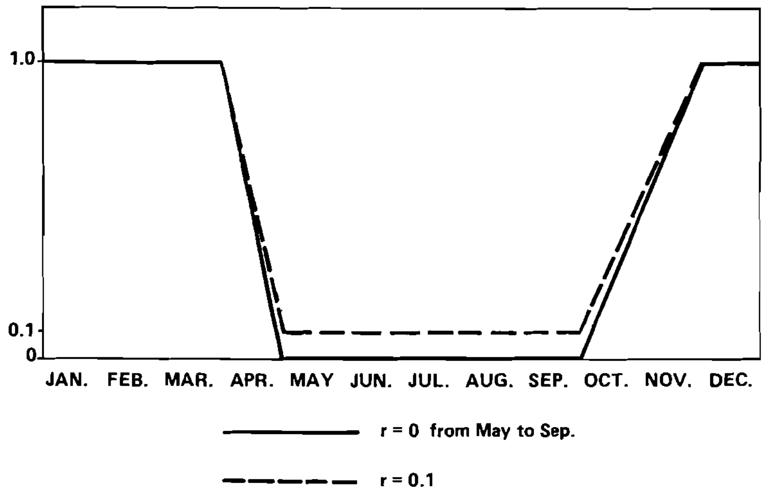


Figure 7. Rates of yearly circulation between thermocline layers.

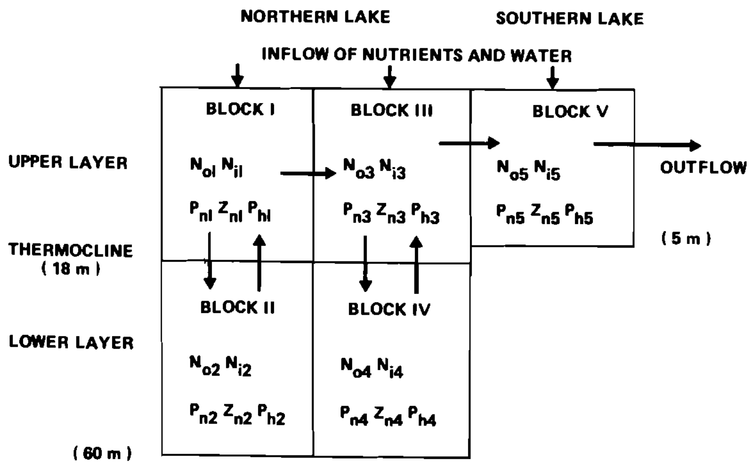


Figure 8. Total nutrients cycle.

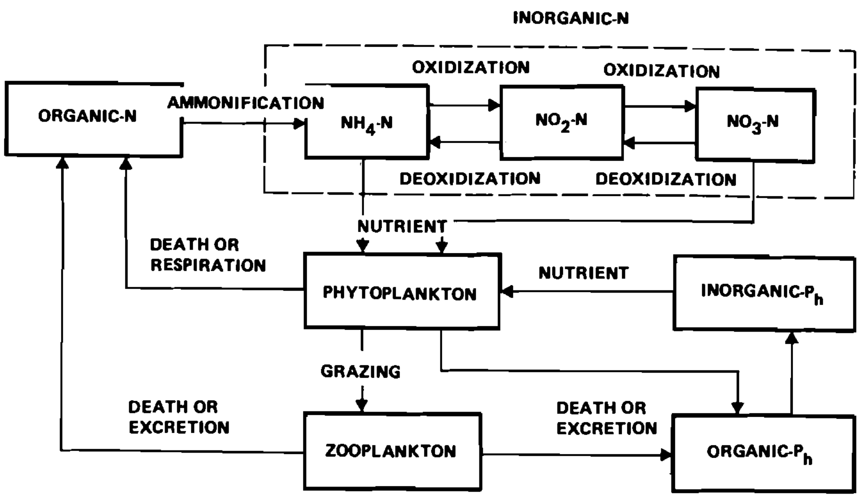


Figure 9. Nutrients cycle in each compartment.

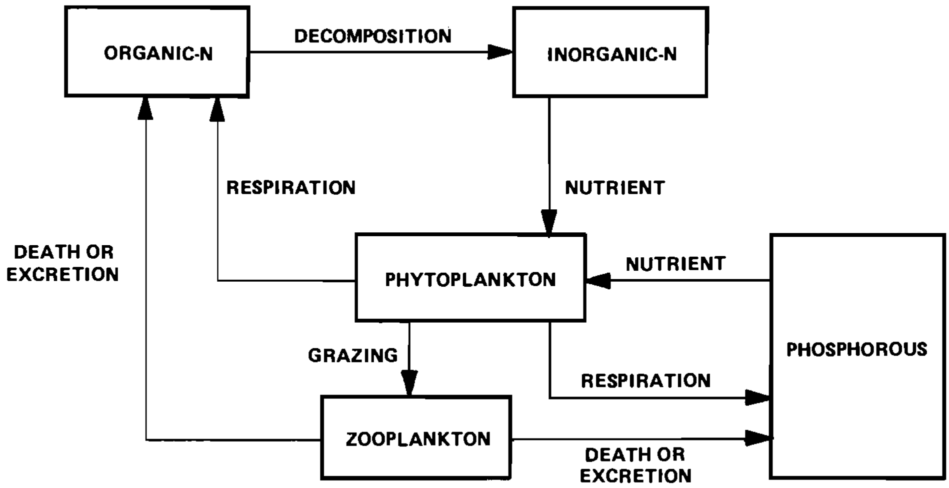


Figure 10. Simplified scheme of nutrient cycle.

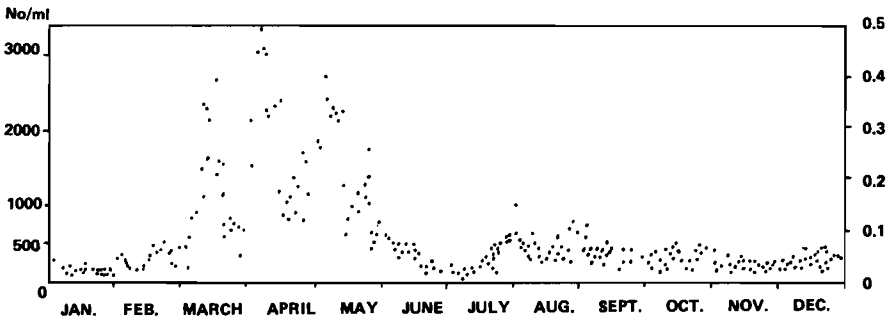


Figure 11. The observed data of the phytoplankton population in the Southern Lake at Keage (Kyoto). The rate of conversion (670 No/ml = 0.1 mg-N/liter).

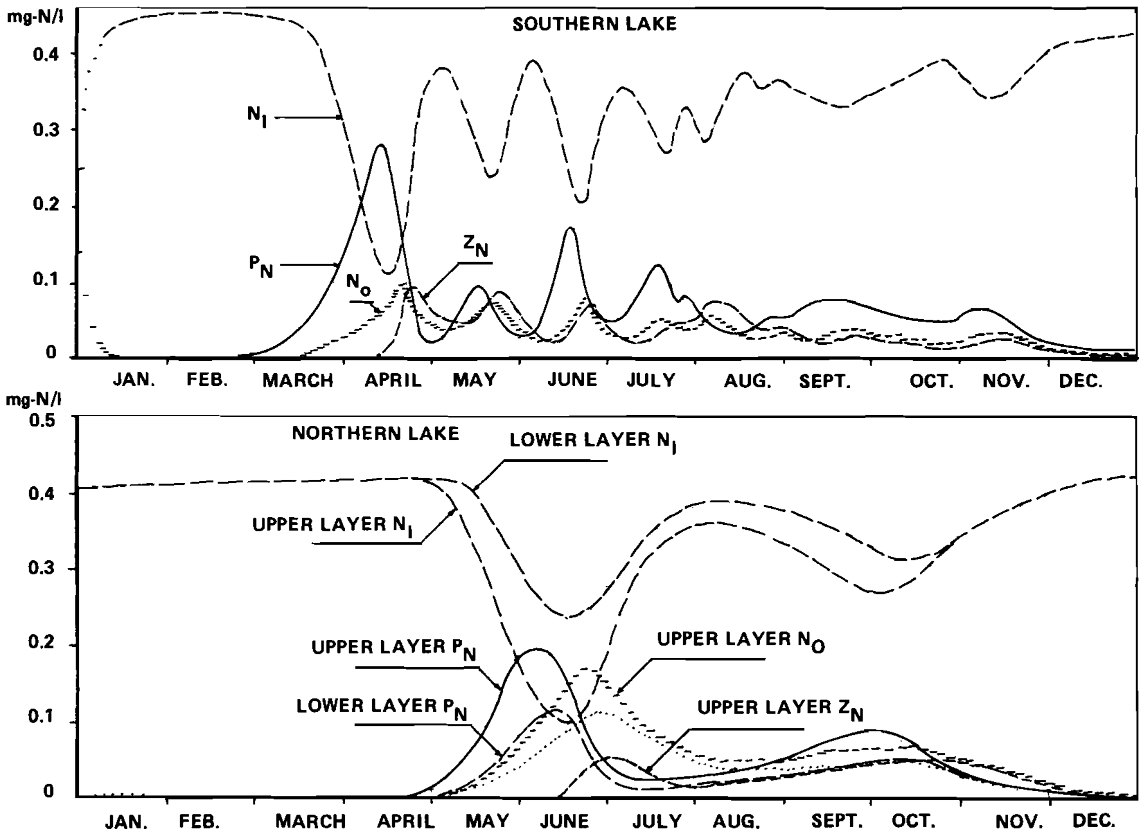


Figure 12. Computer simulation of typical seasonal variations.

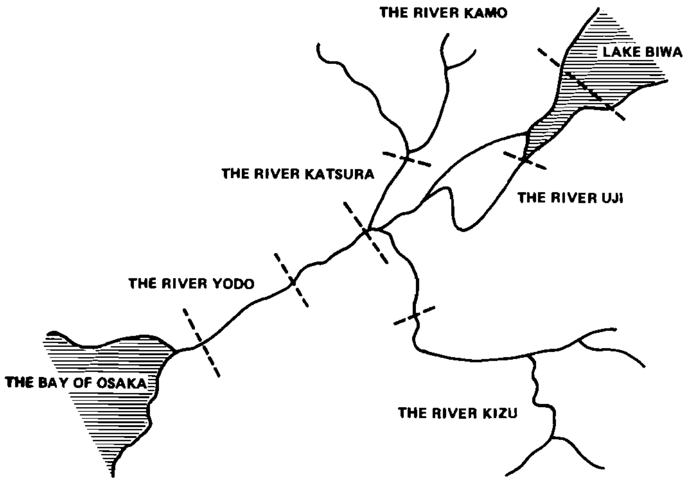


Figure 13. The Lake Biwa and the Yodo River basin system.

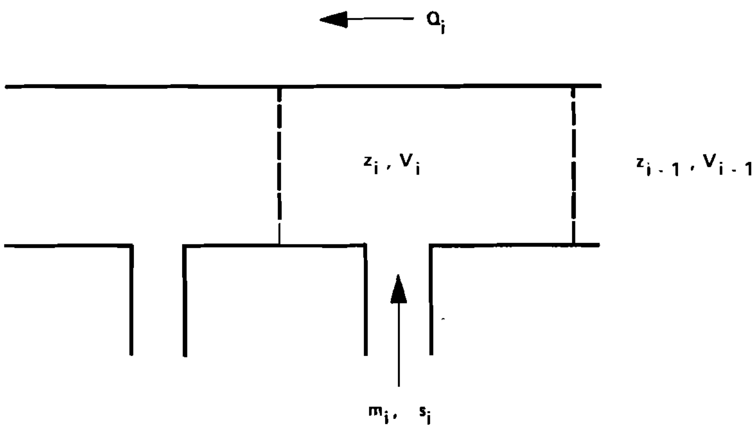


Figure 14. Discrete time model for BOD concentration.

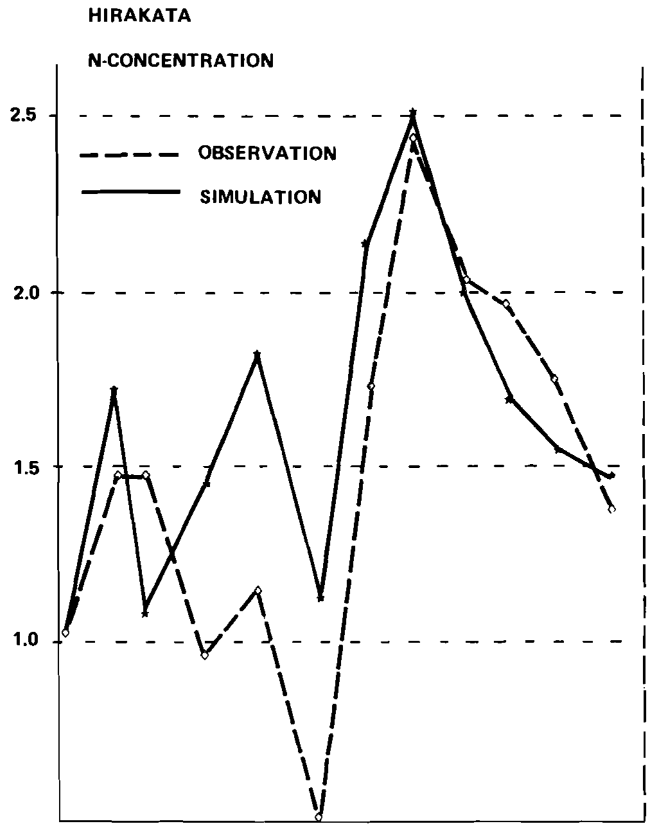


Figure 15. Comparison of simulated and observed water quality, April 1967 to March 1968.

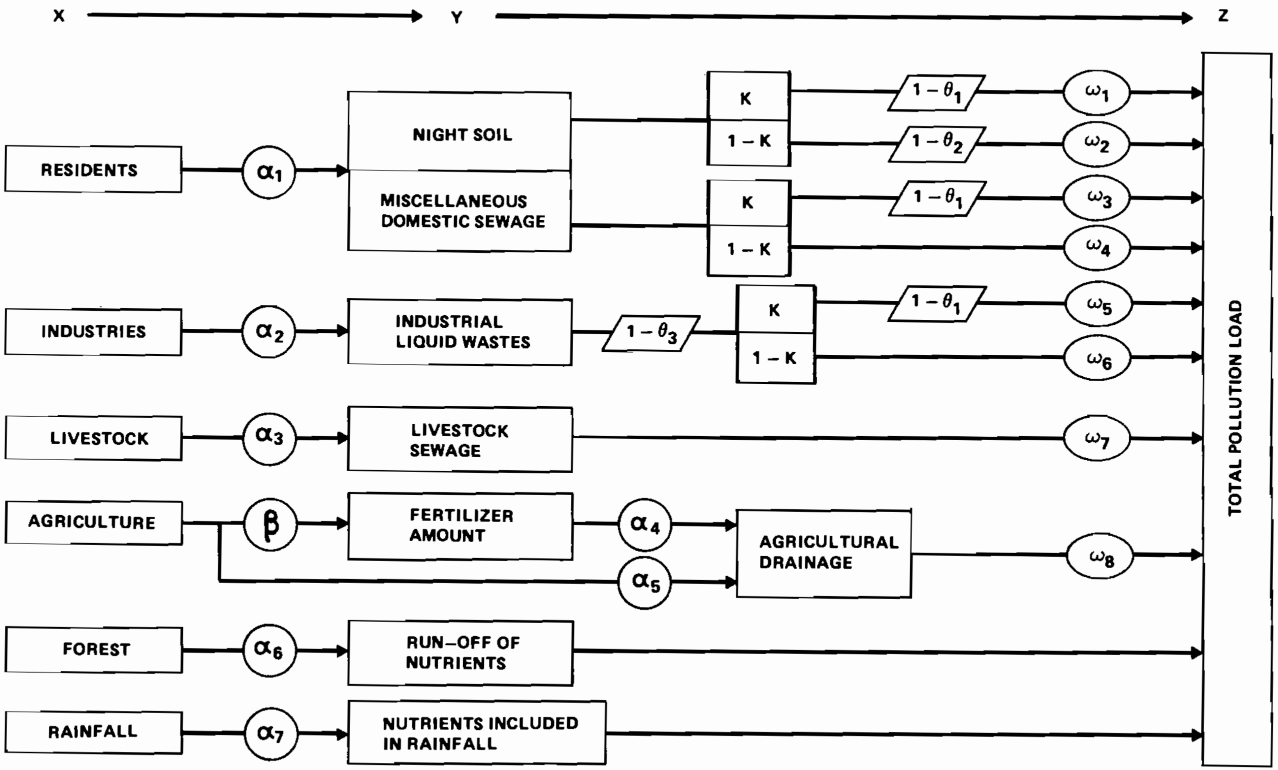


Figure 16. Regional pollution emission model.

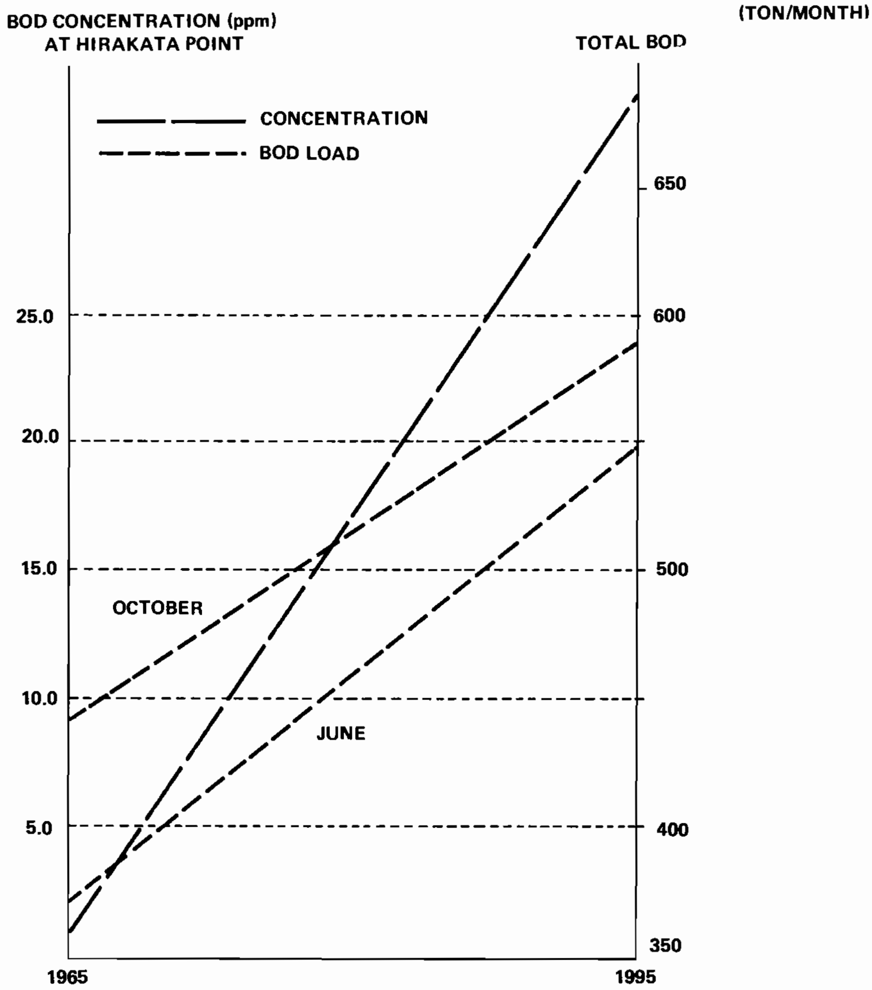


Figure 17. A simulation example of water quality (1).

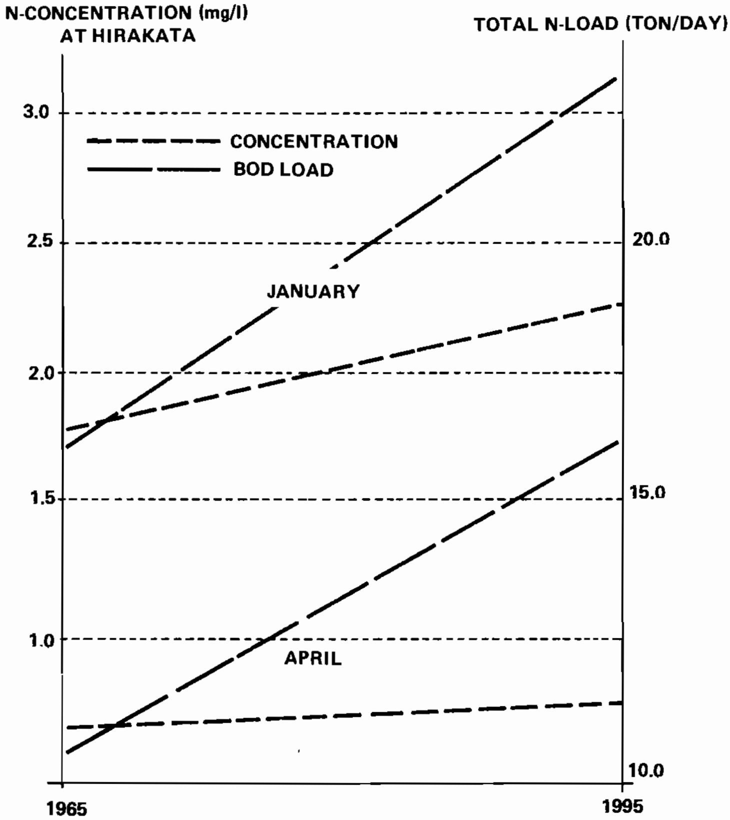


Figure 18. A simulation example of water quality (2).