DYNAMIC MODELING FOR DEVELOPMENT OF JAVA ISLAND ECOSYSTEM

(An Approach to Development of Archipelagic Nations)

By

Fuad Amsyari et al

Team of Island Ecosystem Dynamic Model of
Ministry of Population and Environment of Indonesia

Abstract

As an archipelagic nation, Indonesia consist of thousands of island ecosystems. The development of the nation is supposed to consider such a specific existing ecological condition of the country. Therefore, as an alternative effort to promulgate a strategy for sustainable development of the nation, a study of Java as a complex island ecosystem has been conducted using dynamic modelling approach. the objective of the study is to delineate and assess the prospects of various dominant development variables of the island based on complex but measurable interactions among the components of the ecosystem to determine the most effective development strategy for the area.

A dynamic model for Java Island Ecosystem has been set up based on 14 level variables in the model that represent five components of the island ecosystem, i.e. population variable for population component, food, houses, and fuel variables for population basic need component ; industry-capital, agriculture-capital, and business-capital variables for economic component ; schools and criminals variables for social component; forest, arable-land, agricultural-land, city, and pollutants variables for ecological component. Each level has either two or four rate variables that sum up to 30 rate variables. In addition, these variable is then interrelated by 72 multiplier variables. A computer program has been developed using a compiled basic language to exercise simulation process. The result of study indicated that the best strategy for development of Java Island Ecosystem should be focused to the intensive program on modern agriculture rather than industrial establishement of the area.
(The computer simulation program will also be demonstrated to the conference).

Note : This study is conducted by an inter-disciplinary team that consist of ecologist, economist, engineer, statistician, computer programer, etc., and funded by Ministry of Population and Environment, from 1986-1989. The list of the team is on the annex

Address : Airlangga University, School of Medicine,
Jl. Darmahusada 47, SURABAYA, Indonesia

I. INTRODUCTION

Archipelagic nations are ecologically different from continental nations. It consists mainly of two sorts of ecosystems, namely aquatic ecosystem and terrestrial ecosystems. The open aquatic ecosystems usually dominate the area of the archipelagic nations, while the terrestrial ecosystems consist of several separated islands and therefore each island is practically independent and become a "close" terrestrial ecosystem. The ecological characteristics of an island in an archipelagic nation may be different from the others in terms of various aspects, i.e. the island's physical, biological, and social conditions. As a practical habitat for the population, an island should be well preserved and managed in order to prevent it from damages that subsequently cause inconveniences and even hazards to the inhabitants. The strategy in preserving and managing the islands in an archipelagic nation should therefore be considered as an important part of the National Development Plan.

Indonesia is the largest archipelagic nation in the world. The area of Indonesia is almost equal of those of US. However, about 70% of the area consists of water system and is attached to Indian and Pacific ocean. The terrestrial parts of Indonesia consists of about 6000 inhabited islands, although 70% of 160 million population of Indonesia live in Java island. Various ecological problems have also been arising, including population density, inter-island communication, distribution of natural resources, and environmental pollution.

The National Development of Indonesia is so far dominated by sectoral approach and putting the priority to economic sectors. Such and approach should be combined with sufficient efforts on regional planning in terms of environmental management and setting in order to neutralize/minimize its ecological impacts. A comprehensive review of regional planning in Indonesia has been encouraged and developed.

This paper presents a result of an operational study that elaborate a technique of how to develop a long term regional planning in Indonesia (as an archipelagic nation) based on a comprehensive evaluation of island ecosystems. The project has been initiated and organized by the Ministry of Population and Environment by establishing an interdisciplinary team composed of experts from three Government Universities in East Java. The team consists of various disciplines such as ecologist, engineer, physician, epidemiologist, demographer, statistician, computer specialist, biologist, and behavioral scientist, under direct supervision of the First Assistant Minister of Population and Environment. The team has been working since 1986 up to 1989.

II. OBJECTIVE OF THE STUDY

The objective of the study is to prepare a technique for comprehensive evaluation and prediction of an island ecosystem in Indonesia in order to be able to find effective and efficient ways for island development. This technique would be an

alternative strategy of National Development through a sound environmental long term planning. The study should therefore include situational analysis of the island ecosystem, techniques for prediction if an intervention is going to be applied to the island, and spatial planning of the ecosystem in terms of lay out plan for various development projects.

III. MATERIALS AND METHODS

III.1. Selection of the study area :

Java island of Indonesia has been selected as the study area by two main reasons, namely : 1). it is relatively moderate size island that makes Java not too complex to begin with (particularly in relation to a spatial planning) and not too small either so that Java is considered having various development activities that usually available in a larger island of Indonesia, and 2). Java is the most developed island in Indonesia so that it may provide secondary data on activities within Java ecosystem with adequate reliability.

III.2. Methods of approach

The study has been done through six stages, namely : 1). preparation phase that deals with discussion on basic philosophy of environmental long term planning, its operational objectives, and process ; 2). development of basic structures and functions of a dynamic model of an island ecosystem ; 3). development of dynamic model of Java ecosystem ; 4). establishment of various alternative intervention to the island as scenarios to the model ; 5). constructing a computer simulation soft-ware and running the program to select the optimum development strategy for Java; and 6). setting up a spatial planning for the island based on the output of the simulation program (using a different computer soft-ware and seperated from this report).

Java island was then reviewed and comprehensively evaluated, including the prospective impacts of various alternative interventions to find to most effective and efficient ways of island development in terms of social-economical-environmental improvement of the island and its population.

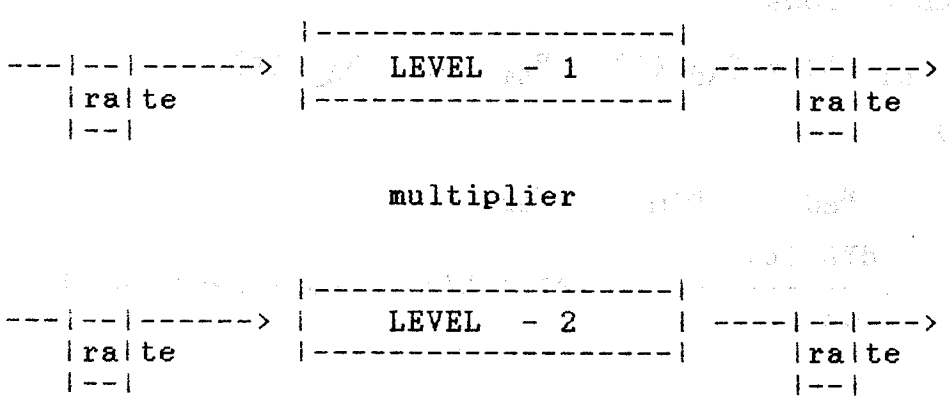
IV. DYNAMIC MODEL OF ISLAND ECOSYSTEM

The development of a dynamic model of island ecosystem is essential to comprehend the complex and interrelated activities within an island ecosystem, to estimate the trend in the future, and to know its respond to an intervention. Therefore most of team activities was spent for establishing Java Island Ecosystem Model, a simplification of the ecosystem using system analysis approach. There are five assumptions that have been taken into account when the team constructed the dynamic model, namely : 1). the island ecosystem, in relation to eco-development,

consists of five major components, i.e. population, population basic needs, economic activities, sociological behavior, and ecological components. Each component may be evaluated as a sub-system ; 2). the interrelation within each component and between components is measured through three groups of variables, i.e. level variables, rate variables, and multiplier variables. (Jay Forrester, 1973) ; 3). The pattern of interrelation between variables and the development of model structure was constructed by group dynamics technique ; 4). Information of Java island was gathered from secondary data available at Provincial and Regency Administration Office ; 5). Functional relationship among variables was estimated by linier and non linier mathematical equation, using mathematical analysis such as Brandon methods, Exponential, Logistic S-curve.

IV.1. Model Structure

The basic structure of an island ecosystem model can be described as follows :



There are 14 level variables in the model that represent five components of the island ecosystem, i.e. population variable for population component, food, houses, and fuel variables for population basic need component ; industry-capital, agriculture-capital, and business-capital variables for economic component ; schools and criminals variables for social component; forest, arable-land, agricultural-land, city, and pollutants variables for ecological component. Each level has either two or four rate variables that sum up to 30 variables. Each rate variable will be interconnected to the others through auxiliaries variables (multipliers) that sum up to 72 multipliers. Therefore the total variables involved in the island ecosystem model are 116 variables. These variables may still be expanded into some other derived variables required by the planner or model users. The selection of variables in the model has been done in such a way so that model may be applicable to measure important development indices within the island ecosystem, e.g. the measurement of economic indices, social indices, and ecological indices. In

addition, the variables included in the model may be also enable the planners to assess various aspects of development activities in the regional plan.

IV.2. Parameter Estimation

The dynamic of the island ecosystem was measured by mathematical functions that relate functionally the interrelation among variables in the model. The 14 level variables as indicated in the model structure will influence one to each other through rate variables and multipliers in the following formulas :

$$R_i(t) = k_i Y_i (t) \qquad i = 1,\ldots..,\ 14$$

$$k_i = f(Y_i, Y_2, \ldots..,\ Y_{14})$$

where R_i is the net value changes of Level variable Y_i,
(i is the sector in the model)

As an example, the dynamic of population level variable can be described as follows :

$$R_A (t) = R_{A1} (t) + R_{Ad} (t) - R_{Am} (t) - R_{Ap} (t)$$

$$= k_A Y_A (t)$$

$$k_A = k_{A1} + k_{Ad} - k_{Am} - k_{Ap}$$

$$RA (t) = \frac{dYA (t)}{dt} = (kA1 + kAd - kAm - kAp)\ YA (t)$$

where :

A	= population sector
R_{a1}	= birth-rate
R_{Ad} (t)	= inmigration-rate
R_{Am} (t)	= death-rate
R_{Ap} (t)	= outmigration-rate
Y_A (t)	= population at time t
k_A	= net-coefficient of population changes
kA1	= f (educational state, income per-capita life expectancy, population control program)
kAm	= f (population density, pollution level, food per-capita, health care system)
kAd	= f (economic activities, income per-capita)
kAp	= f (economic activities, income per-capita, population-arable land ratio)

There are 103 mathematical functions involved in the model and represent functional relationship among variables. The type of the functions, whether it is a linier, exponential, logistic, or S-curve, was determined by deductive method, while the formulas were constructed by fitting the data from Java island (15 years information, from 1971 to 1985), using Brandon or Newton techniques.

A computer simulation program was then developed using Basic Language for IBM PC. The program consists of three main parts, namely : 1). data input instructions that include input of all variables involved in the model and the mathematical functions, 2). instructions for computation of mathematical formulas within a for-next loop related to time dimension, 3). output instructions, including plotting diagrams, that present results of interaction among variables in the model in terms of values of various important variables in a particular year to be read by the planners.

IV.3. Model Validation

Validation of the model was done by double checks. First, data of 1971 was entered to computer and run. The values of level variables in 1980 from computer results were compared to the data from Java island. Five percent deviation was considered as maximum acceptable difference. Second checking was done by comparing computer results of 1984 for variables related to socio-economic-environmental indices to data for the same variables. Another five percent deviation was considered as maximum acceptable difference.

V. RESULTS AND DISCUSSION

V.1. Situational Analysis of Java Island Ecosystem

1.1. Geography of Java Island Ecosystem

1.1.1. Position	:	6^{o} - 40^{o} N-S 105^{o} 20` - $114^{o}$ 20` E-W
1.1.2. Area	:	132,187 sq. km or 13,218,700 Ha
1.1.3. Topography	:	In general Java Island Ecosystem is flat and only mountaineous in several parts in the middle area. The distant from East to West is about 900 km while the average distant from north to south is about 170 km.

1.2. Population.

	1971	1985
1.2.1. Population Size (thousand)	76,086	99,522
1.2.2. Population by Province (thousand)		
Jakarta	4,579	7,824
West Java	21,624	30,733
Central Java	21,877	26,934
Yogyakarta	2,489	2,967
East Java	25,517	31,039
1.2.3. Population Increase		
CBR	0.038	0.031
Natural Increase	0.020	0.020
1.2.4. Long-life Migration (thousand)		
Outmigration	1,935	3,650
Inmigration	583	1,385
1.2.5. Pop. Density (per sq.km)	578	753

1.3. Population Basic Need

1.3.1. Food (million ton)		
Rice Production	11.77	13.32
Corn Production	1.37	3.39
Cassava Production	8.43	9.68
Animal Protein	0.044	0.384
Non-Animal Protein	1.244	1.698
Fat Production	0.266	0.255
Vegatable Production	1.46	1.59
Fruit Production	2.43	5.08
1.3.2. Fuel Consumption (mill.barel)	8.759	47.149
1.3.4. New Housing Construction (By Private Developers)	-	218,252

1.4. Economic Activities.

1.4.1. Economic Welfare		
Income per capita (Rp. on constant price of 1975)	55,067	155,614
Unemployment (person)	3,742,896	5.231,452
Gini Coeffisien	0.3366	0.3699
Economic Growth	10.94 %	1.96 %

1.4.2. Sectoral Activities

Industries	20 %	34 %
Services	28 %	41 %
Agriculture	52 %	25 %

1.5. Social Welfare.

1.5.1. Public Health

Life Expectancy at Birth	46 th	56 th
C.D.R	0.0126	0.0109
I.M.R.	0.130	0.095

1.5.2. Education (Ratio of Student to Related Population)

Elemantary School	92,5 %	100 %
Junior High School	28 %	59,5 %
Senior High School	18 %	58,1 %

1.5.3. Social Pathology (criminal)	135.238	270.568
1.5.4. Obidience to Religion (% prayer)	54 %	33 %

1.6. Bio-Physical Environment.

1.6.1. Land Use

Area of Forest (thousand Ha)	2,986	3,039
Agriculture	4,258	4,756
City and Industries	537	1,005
1.6.2. Rainfall (mm /year)	2,559	2,197
1.6.3. Maximum Ambient Temperature	34.9°C	36.4°C
1.6.4. Pollution Level (rate to TLV)	0.986	3.132

V.2. Alternative Development Strategies

The development strategy for Java Island Ecosystem was based on policies of 5 important development sectors, namely : population, economic, social (education and social-pathology), and environmental policies. Policies on each sector was set up into three alternatives. Therefore development strategies for Java Island System in this study may be set up into 243 (3^5) alternatives.

The alternative policies for each development sectors are as follows.

2.1.

ALTERNATIVE POPULATION POLICIES	Target for year 2000		Transmigration per year
	C.B.R	C.D.R	
1. Pessimistic	0,025	0,01	100.000 persons
2. Moderate	0,025	0,007	500.000 persons
3. Optimistic	0,020	0,007	400.000 persons

2.2.

ALTERNATIVE ECONOMIC POLICIES	Capital investment (billion Rp./yr) :		
	Industry	Business/Service	Agriculture
1. Industries	2.483	870	447
2. Business/Service	1.398	1.427	975
3. Agriculture	342	370	3.088

2.3.

ALTERNATIVE POLICIES ON SOCIAL PATHOLOGY	Rehabilitation Program For Criminals per Year
1. Responsive	Rehabilitation of 100 criminal per year
2. Moderate	Rehabilitation of 1000 criminal per year
3. Intensive	Rehabilitation 20.000 criminal per year

2.4.

ALTERNATIVE EDUCATIONAL POLICIES	Development of School Facilities
	Addition of Student's Seat in School
1. Maintainence	: Up to 400.000 seat/yr for 15 years
2. Improvement to High School	: Up to 800.000 seat/yr for 15 years
3. Improvement to Higher Education/ Universities	: Up to 1.000.000 seat/yr for 15 years

2.5.

ALTERNATIVE SPATIAL PLANNING OF JAVA ISLAND	Lay Out Plan for Java Island for Yr. 2000		
	Forest	Agriculture	City/Industries
1. Island City	20 %	40 %	40 %
2. Island Agricult.	25 %	60 %	15 %
3. Buffer Island	40 %	50 %	10 %

V.3. Recommended Strategy for Development of Java Island Ecosystem

Those 243 alternative development strategies (code number 802 - 1043) were then tested simultaneously in the computer simulation program (the software can be demonstrated in a seperate occasion). The result of the simulation can be summarized as follows:

ALTERNATIVE DEVELOPMENT STRATEGIES FOR JAVA ISLAND ECOSYSTEM

CODE	POPULATION			ECONOMIC			EDUCA-TION	SOCIAL PATHOL	SPATIAL PLAN			NOTE
	CBR	CDR	TRANS	IND.	BSN/SV	AGRI			FRST	AGRI	CITY	
802	2.5	1	100 ths	1398	1427	975	400	100	20	40	40	
856	2.5	1	100 ths	2483	870	447	400	100	20	40	40	
996	2	.7	400 ths	342	370	3088	400	20000	25	60	15	
1008	2	.7	400 ths	342	370	3088	1 mln	100	25	60	15	
1014	2	.7	400 ths	342	370	3088	1 mln	20000	25	60	15	best plan
1016	2	.7	400 ths	342	370	3088	1 mln	20000	40	50	10	

Note:

* cd 802 : the on going development plan
* cd 856 : advance industrialization of Java
* cd 996 : best alternative based on economic consideration
* cd 1008 : best alternative based on environmental consid.
* cd 1016 : best alternative based on social consideration
* cd 1014 : best alternative based on simultanious economic, environmental, and social consideration

The impact of the development strategies into various condition of Java Island Ecosystem can be described as the followings: (see annex 2 for the trend resulted from the computer simulation model)

VI. CONCLUSIONS

1. The ecological characteristics of Archipelagic Nations should strongly be considered in National Development Strategy, particularly in relation to long term environmental planning.

2. Sectoral approach in National Development prone to put emphasis into each individual sector and to neglect both the integrative nature of development and interrelation between the sector and its environment. Therefore sectoral approach should be combined with sound regional planning in terms of setting, preserving, and managing the environment for long term perspective.

3. Dynamic Model of Island Ecosystem (ISLEC DYNAMO) is a technique that qualify as soft ware technology for long term regional planning in Archipelagic Nations for it is able to evaluate the island ecosystem comprehensively, to estimate the prospective impacts of any intervention/development policies to the ecosystem, and to provide basis for a reasonable lay out plan for the island in an integrative way.

4. The development of Java Island Ecosystem should be directed into modernization of agricultural development rather then advance industrialization. In addition, population and health program, education facilities, and control to criminals were found very important to the result of development process of the area.

5. The Spatial Planning of Java Island Ecosystem should be directed into an agricultural ecosystem in which major area allocation for agriculture should be maximum, where as the industry and cities limited to 15 % of total land area and the forest should be preserved for 25% of the area.

References :

1. Forrester, Jay W. Principles of Systems, seventh edition. Wright-Allen Press, Inc., Cambridge, 1973.

2. Kavarof, V. Cybernetic Methods in Chemistry and Chemical Engineering. Mir Publisher, Moscow, 1978.

3. Meadows, Ronders, and Behrens. The Limit to Growth. Universe Book, New York, 1972.

4. Philips, S Bernard. Social Research, Strategy and Tactics. Macmillan Publ. Co., New York, 1976.

5. Sharif, N and Adulbhan, P. System Models for Decision Making. Asian Institute of Technology, Bangkok, 1978.

6. Sawaragi and Akashi. Environmental System Planning, Design, and Control. Proceeding of the IFAC Symposium, Kyoto, 1977.

7. Uchida, Yukio. A Hierarchical Multilevel Approach to Environmental Planning in a System of Regions. Proceeding of the IFAC Symposium, Kyoto, 1977.