INSERTION OF INPUT-OUTPUT MODEL INTO SYSTEM DYNAMIC APPROACH

Fuad Amsyari PhD

Experts Team of BAPPENAS (National Planning Board),
Graduate Program of Airlangga University,
Darmahusada 47, Surabaya, Indonesia.

Abstract

Input-Output Model (I/O model) is an approach developed in economic world for development planning of a Nation. The model founded by a Nobel Prize Winner, Prof. Leontief, focused the operation on the determination of production of economic commodities needed for development of a nation. The mathematical aspect of the model requires matrix analysis using equation (I-A)*X=Y as the basic calculation. Surprisingly, I/O model has received wide appreciation for calculating the economic of many nations, including developed countries such as US, Denmark, and Japan, and developing countries such as Indonesia as well.

On the other hand, system dynamic approach founded by Prof. Jay Forrester are getting more attention in recent years and people start thinking of using the approach to solve various national development problems. However, since the application of the technique for establishment of world model, no one country yet uses comprehensively the approach to the national development planning. There has been a case study using the technique to exercise the development of Java Island Ecosystem in Indonesia, but it still needs to be more promoted for further application of the theory.

As the development process of a nation does not anymore cover only economic concerns, while the environment and social dimension of a country are getting more attention, a national development planning will certainly requires a more comprehensive approach to analyze alternative scenarios to the development of the country. In such a case system dynamic approach seems to meet the requirement of a national development planning.

Since I/O Model has been widely used in many national development plans while the needs for comprehensive approach is required, it is then practical to combine both techniques for setting more efficient and effective national development planning. It would be a good exercise to include

the insertion of the I/O model into a broader system dynamic technique that cover comprehensive analysis of simultaneous economics, environment, and social variables of development process. Level Variables of the system dynamic technique will represent all dominant development variables including economic, environment, and social sectors, whereas I/O model will explain more in detail the economic aspect of the system, particularly in delineating the economic scenarios required in a dynamic modeling of development planning.

(Note: The concept presented in this paper was induced during intensive discussions of Experts Team of BAPPENAS in the efforts to prepare the second Long Term Development Planning of Indonesia lead by Dr. Sayuti Hasibuan, the Deputy Chairman of BAPPENAS)

I. INTRODUCTION

The concept of National Development Planning has been improved from time to time. People keep looking for a better and comprehensive thinking but feasible to carry out. Starting from the end of the second World War up to 1960 the national development planning was viewed as an economic improvement of a country. It was measured by national economic growth, the increase of Growth National Product, and was recognized as Growth Oriented Strategy. In early 1970 the concept was moving into a deeper view as GNP indices was unable to uncover probable vast poverty among population. The new concept of national development was called Basic-Need Oriented Strategy in which the fulfillment of the economic basic need of the people was the final objective of the development process. By the end of 1970 the strategy was argued as still unsatisfactorily as that the basic-need of the people were not only economic aspects. The people need more then economic well-being; they need a better human quality. The indices of a national development process was then called as Physical Quality Life Indices (PQLI) that included health and educational condition in addition to economic status of people. In early 1980 the concept of development planning was not limited anymore on human quality, but also included environmental aspect of a society. The strategy was then called as Eco-Development. Furthermore, in an ASEAN Meeting of Ministry of Environment of late 1980 there was an understanding that a national development process should also be able to improve overall social and environmental condition of the country and keep maintaining the process in an accelerated way. They called the strategy as Sustainable Development. Such a view of a national development was certainly a better comprehension of development process itself but still requires approaches and

techniques to materialized it.

The relatively rapid progress of national development planning concept was not unfortunately supported by proportional technological improvement in planning. The operational approach of the national development planning was still dominated by economical methods called as Input-Output Model. This economic Model was certainly attracting as it promised a technique of how to calculate quantitatively the economic activities in a national scale, while a more comprehensive technique was not yet considered feasible. The founder of the model, Prof. Leontief has once experienced a unique phenomenon in a national economic activities that provoked him creating the model. He found a complex but measurable relationship between increasing industries in Chicago with demand for agricultural products in different states. He was then observing a pattern of relationship among various economic products and watched the behavior. He finally wrote the model that was quickly accepted by others as a unique and feasible technique to calculate economic planning of a nation. This model was then applied in many countries up to date as a dominant approach to national development planning.

II. CONCEPTUAL FRAME WORK OF INPUT-OUTPUT MODEL

Input-Output (I/O) Model is a mathematical model in macro-economics and is used to measure quantitatively economic activities within a national scale. The model considers the economic world as two areas of concern, namely Production and Demand sides. There will be an equilibrium between those two economic dimensions and therefore the economic activities can be analyzed through either side. The model then focuses the analysis from the Production side of economics.

In a production activity of an economic goods there will be a system involving Input, Process, and Output. Input for a production activity of a certain commodity is usually an Output of another production process and or the Output of its own production. For example, production of economic commodity Y needs an input X which actually an output of another production process. The production process that produce commodity Y may also be used as an input of production of another commodity, say Z. In addition, there will also be a certain quantities of Y needed by the community as consumption (are not used in any production process) which is called as a final demand of the community. Such a kind of inter-relationship creates an economic production web to meet a set of community final demand. Those complex interaction is then simplified as a model in order to calculate quantitatively the overall economic

commodities needed for a national development.

The I/O model started with static approach in which a planner is only estimating the quantity of various economic products needed in a particular time given a certain community demand for consumption. The model was then developed into a dynamic model by including the capital stocks factor and calculating past, current, and future output required. However, the basic assumption of the model is mainly laid upon three point, namely: 1). Economic activities can be analyzed through production side approach; 2). No two or more commodities are produced jointly by a production process; and 3). In any production process all inputs are employed in relatively fixed proportion.

The mathematics of I/O Model based on a matrix analysis. It starts with a simple matrix calculation that involves the solution of a set of N simultaneous linear equation in N variables. N means a number of economic commodities required in economic activities for a national development planning. The basic static I/O model is of the form:

$$x - Ax = y \qquad \text{or} \qquad (I - A)\, x = y$$

The dynamic I/O Model will be more complicated as it includes stock capital in the calculation, and the mathematics is usually expressed in formula as follows:

$$K(est) \geq a1\ x1 + a2\ x2 + \ldots\ldots + an\ xn$$

I/O Model is quickly accepted as a technique in national development planing for it provides various advantages, i.e. rational, easy to understand, requires relatively simple mathematics, and can be applied with relatively moderate budget and efforts. I/O Model will usually solve development problems in terms of what product needed in a society (e.g. rice, steel, and tire), how much production of each commodity required by the people as final consumption (e.g. so many tons of rice, tons of steel, and millions of tires), and then the model calculates the exact quantities of those commodities to be produced after considering the complex process of production. However, I/O Model contains limitation if to be used in a comprehensive national development planning due to three major constraints, namely: 1). concern on economic analysis; 2). using production side approach; and 3). calculate the quantity of production needed after a set of final consumption is set up. Those constraints will be a limiting factor if one is to calculate complex development process in a national development planning in which the population is dynamic, natural resource is limited, and pollution is affecting the production efficiency.

III. SYNCHRONIZING THE I/O MODEL AND SYSTEM DYNAMIC APPROACH IN THE COMPREHENSIVE NATIONAL DEVELOPMENT PLANNING.

The concept of Sustainable Development requires a comprehensive analysis of a nation as a National System that consist of three major sub-systems, namely: economic, social, and environmental sub-system. The economic sub-system consists of production and demand of industrial, agricultural, service, and business activities. The social sub-system comprises population, culture, and social pathology. The environmental sub-system comprises atmospheric, hydrospheric, lithospheric, and biospheric components of the nation. Every sub-system provides a lot of development variables that should be observed and monitored from time to time. The changes of those variables in time dimension can be counted as the dynamic of the national system. Therefore a national development process should include the planning and evaluation of those overall components of the national system, i.e. improving the economic, social, and environmental sub-system inside the country. The management of the nation means the management of the national system in terms of planning and evaluation of those three sub-systems simultaneously.

From the system analysis point of view, those three sub-systems inside the national system will not stand separately. Instead, they will interact one to each others in complex ways. The economic sub-system will be dependent on the status of social and environmental sub-systems and vise versa. Therefore the planning of a nation will not be anymore economic bias but should cover those all components of the system including measurement of the interrelation among those three sub-systems.

Such an area of planning will certainly be very complex but still possible to control. System dynamic approach, an approach founded by Jay Forrester, is one of alternative techniques to solve the development planning of a nation. The world model organized by Club of Rome has exercised the system dynamic approach that was found feasible to observe the dynamic of the global activities. Therefore the system dynamic has a great potential as a technique to solve a complex problems in a national development process. Unfortunately the system dynamic approach needs relatively sophisticated mathematics to be used to measure the inter-relationships among various variables developed in the model. The process becomes more complicated if the model includes social variables. The building of a model for a national system will certainly include a lot of social variables that requires a lot of different mathematical equations to represent different type of interaction among

development variables.

The basic rational of dynamic modeling itself can actually be categorized as easy to understand, i.e. the changes of Level Variable will be determined by Rate Variable and the changes of rate variable will be determined by Multipliers. However, the operational aspect of modeling is relatively complex involving a lot of data and calculation. The decision makers usually loose the process and rely fully to the model builder. This complex process of dynamic modeling usually discourages the decision makers. This may explain why system dynamic approach was not quickly accepted as a technique in national development planning. People will usually be unable to look into the internal process of the model as easy as they look at the I/O Model.

The I/O Model, in the other hand, will certainly capable to measure quantitatively the dynamic of economic activities in the economic sub-system of the national system. However, the I/O Model will be unable to measure the dynamic of environmental sub-system as the environmental most components have been set up and produced by the natural process. The social sub-system will also be difficult to measure by I/O Model as the social component can not also be fully considered as production side of economics. It is hard to agree if the population growth is considered similar as rice production in the economic term. The dynamic of criminal can not also be considered as a production side of economic either as no one ever consciously planning to produce criminals. The recent development of I/O Model was actually geared to fill this gap, namely trying to include and calculate quantitatively labor and environmental requirement of an economic production activities (Duchin, 1990).

The dynamic and the interrelationships among economic, social, and environmental sub-system in a National system may still be presented by a dynamic modeling of system dynamic approach. For example, the Population and Criminal can be categorized as Level Variable representing the Social sub-system; Forest, Arable Land, Fresh Water, and Pollution will represent Environmental sub-system; and Industrial Capital, Agricultural Capital, Service Capital, and Business Capital will represent Economic sub-system. Rate variable of each Level Variable will then be developed relevant to each individual level variable, e.g. birth rate, death rate, and rate of migration for the dynamic of Population level variable. Each of rate variable will be attached to various multipliers and those multipliers may interrelated one to the others covering the overall national system. Such a model has been exercised for development of Java Island Ecosystem of Indonesia (Fuad Amsyari 1991). The total variables involved may be hundreds and can be structured simultaneously within the dynamic modeling to form a web of

interdependent development variables from economic, social, and environmental sub-system simultaneously.

The following diagram will illustrate a national system in a schematic way and shows how the three sub-systems will influence one to the others. A dynamic model can be developed based upon this scheme. The mathematical formula to measure quantitatively the Level, Rate, and Multiplier Variables in the model can be set up using retrospective data and results of specific studies. The dynamic model will make the planner enable to test various alternative development scenarios (consisting of the strategic variables of those three sub-systems) through a computer simulation program that can be specifically made up for these purposes (Fuad Amsyari 1991).

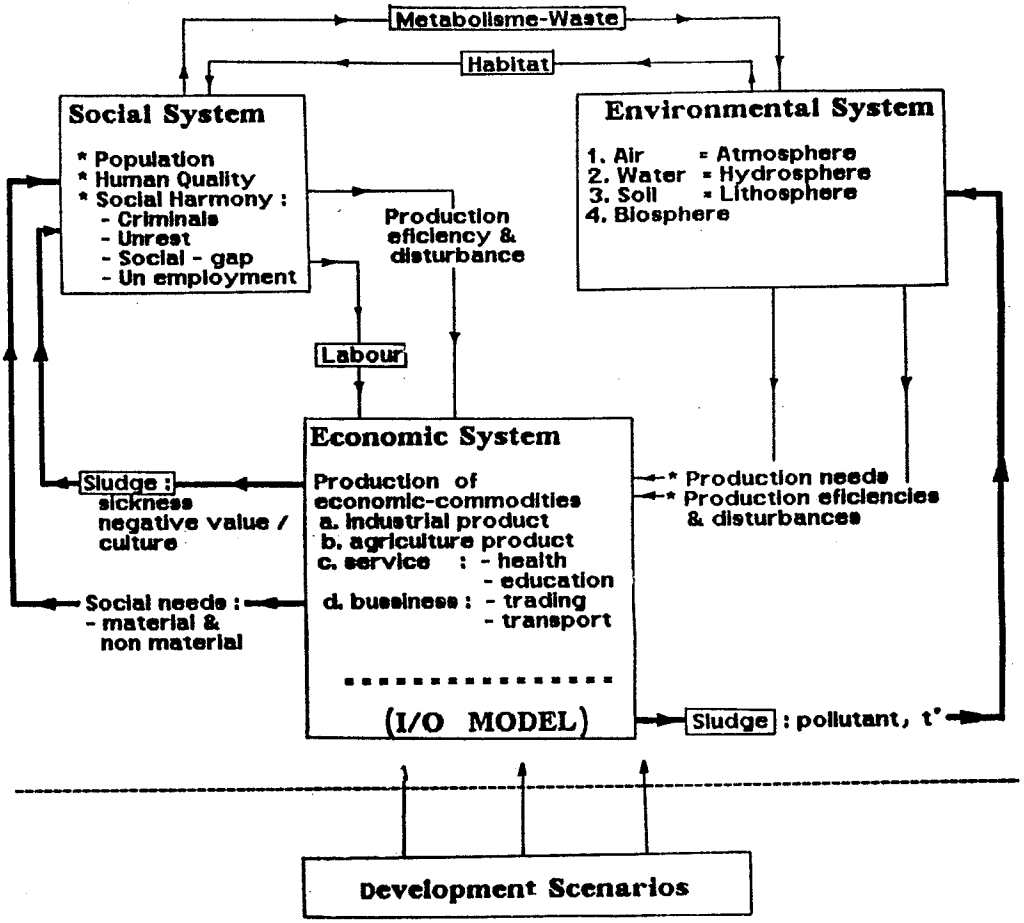
From the dynamic modeling there will be a decision on which development scenario found most favorable to the nation. Such a grand scenario should certainly contain various quantitative set-up of economic, social, and environmental policies. The economic set-up of the scenario may consist of quantitative values of industrial, agricultural, services, and business capital required by the national development representing Level Variables of the economic sub-system. The I/O Model is then plugged in to delineate detail economic sectoral planning of the economic level variables of the dynamic model. In addition, one may start from I/O Model to develop alternative economic sectoral planning to be included in the quantitative economic set up of grand development scenarios (covering economic, social, and environmental aspects) to be tested by the dynamic modeling of system dynamic approach.

References

Duchin,F. and Szyld,D. (1985). A Dynamic Input-Output Model with Assured Positive Output. Metroeconomica vol. XXXVII, Ottobre - Fasc. III, Bologna.

--- (1990). The Conversion of Biological Materials and Wastes to Useful Products. Structural Change and Economic Dynamics Vol I. no. 2:243-261.

Fuad Amsyari et all (1991). Dynamic Modeling of Java Island Ecosystem. Proceedings of System Dynamic Conference, AIT, Bangkok.


Metabolisme-Waste
Habitat
Social System
* Population
* Human Quality
* Social Harmony :
- Criminals
- Unrest
- Social - gap
- Un employment
Environmental System
1. Air = Atmosphere
2. Water = Hydrosphere
3. Soil = Lithosphere
4. Biosphere
Production eficiency & disturbance
Labour
Economic System
Production of economic-commodities
a. industrial product
b. agriculture product
c. service : - health
- education
d. bussiness : - trading
- transport
(I/O MODEL)
Sludge : sickness negative value / culture
Social needs : - material & non material
* Production needs
* Production eficiencies & disturbances
Sludge : pollutant, t°
Development Scenarios