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to Promote National Economic Development

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NOTATIONS USED IN THE MATHEMATICAL MODEL

$\bar{b}$	Value of average annual production
B	Present value of benefits
c	Yearly cost
C	Present value of costs
$\bar{C}_\tau$	Allocated budget for plan period τ
D_τ	The total production demands vector at the beginning of plan period τ
g	Average annual growth rate of GNP
i	Annual discount rates
$k = 1, 2, \ldots, K$	Project number
K	Total number of projects
$\ell = 1, 2, \ldots, n$	Type of project output (irrigation water, hydropower, etc.)
M_τ	Vector of projected imports at plan period τ
P_k	k-th project
P_τ	Set of projects selected for implementation at the beginning of plan period τ
s	Yearly cash flow
S	Net present worth
$t = 1, 2, \ldots, T$	Number of years
T	Project life
$v = 1, 2, \ldots, V$	Number of projects going out of use (vanishing)
W_τ	Vector of projected intermediate demands τ
Y_τ	Vector of projected final demands τ
δ	The increment in total production levels between two successive plan periods
δ^ν	The vector of target levels of outputs to be met by new projects
θ_k	Length of construction (or project maturity) period of the k-th project
ν	Topscript indicating target levels of outputs to be met by new projects
ρ	Number of years in each development plan period; five years is the span most commonly adopted by developing countries
$\tau = 1, 2, \ldots, N$	Number of development plan period
τ_o	Subscript used to indicate reference to the base year

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Wendim-Agegnehu Lemma

ABSTRACT

The methodology developed in this paper is designed to facilitate the selection and timing of water resources projects to optimally achieve "a priori" specified national economic development through desired strategies. The methodology is composed of several analytical procedures.

The input-output model is used to simulate the national economy thus further facilitating consistent projections of the elements of final demands in accordance with the national economic development objectives and strategies, and assessing the total and incremental requirements for sectoral outputs of goods and services at designated future time periods. A mathematical model for the selection and timing of water resources projects for their implementation, in other words for the formulation of an optimal national water resources development program, has been developed and its application demonstrated on an example problem. The model incorporates important factors such as economic efficiency of projects, demand targets for project outputs of goods and services necessary to achieve desired national economic growth, resources capabilities and limitations, and project interrelationships. Incorporation of these and other related factors makes the model reflective of the real world problem it is intended to aid in solving.

The application on an example problem convincingly indicates it to be a very useful tool indeed in the national economic planning process. This exercise also reveals the avenues for further research and improvement.

Chapter 1
INTRODUCTION

Despite the fact that more and more countries are exercising some form of economic planning, and despite the fact that the literature on planning and project evaluation for developing countries is literally mushrooming, work concerning the extremely vital subject of project selection and timing for implementation to enhance national economic development is disappointingly meager and incomplete. After all, the culmination of the plan formulation process is the selection of a recommended plan of action--a fact recognized by many.

Furthermore, most of the works on project evaluation, and selection, under conditions associated with developing countries end up using the competitive market model (by virtue of the implied assumptions underlying the choice of such parameters as interest rates and selection criteria) which does not accurately represent the real situation in these countries (even though this is usually acknowledged at the beginning) at all.

The objective of this study is to develop a methodology composed of rigorous analytical procedures based on sound optimization techniques for the selection and timing of the implementation of water resources projects to enhance national economic development. "Project selection and timing" is understood in this study as the decision-making process of determining which projects should actually be implemented and when. The irreversibility of such decisions coupled with the resource intensiveness of water resources projects, and hence the costliness of a wrong decision, make the selection and timing of water resources projects a crucial matter in the entire process of national economic development planning.

In this paper the major elements relevant to the selection and timing of water resources projects are studied and a methodology composed of analytical procedures for making such decisions directed to achieving national economic development goals and targets within its resources capabilities is developed. Even though the methodology may prove to be useful in both economies where the operative policy is either indicative or directive planning, it should be most useful in the latter.

The results of the study are presented in the following chapters. Chapter II exhaustively discusses the need for central planning to ensure balanced and sustained national economic growth and articulates the place of project selection and timing in the planning process. A survey of the present practices of project selection and timing given in Chapter III, while pointing out the merits of some of the leading works, articulates the necessary features of the real world to be depicted in the decision making that these studies are lacking. The suggested methodology is presented in Chapter IV. An illustrative example, where the mechanics and the workability of the methodology are demonstrated, is given in Chapter V. Conclusions and recommendations for further research, as well as reflections on relevant lessons learned, are given in Chapter VI.

The scope of the study is limited to considering only "the enhancement of national economic development" out of the three major objectives of water resoures development (Chapter IV). This is mainly because of the fact that the valuation of benefits and costs (primarily benefits) pertaining to the other two objectives is yet an unresolved issue, and those suggested so far are noncommensurate with that of the basic and conventional development objective.

Furthermore, due to the unavailability of the necessary data in the appropriate form and kind, application of the methodology could not be demonstrated on an actual case of a given country. However, the example problem set up is as good, if not better, for it has more detail because separate parts of the data used represent actual cases which have been pulled out of documents of several countries.

Chapter II
ECONOMIC DEVELOPMENT AND PLANNING

The overall purpose of this chapter is to indicate the need for and the appropriate place of the methodology, suggested in the present study, for the selection and timing of water resources projects. The methodology could find application in almost any place; yet, it would be especially useful where simultaneous development of numerous sectors is to be carried out according to a long-range perspective plan that specifies the desired goals for the entire economy. Among possible other uses that the methodology may have, in addition to selecting and timing of water resources projects, is that it could help indicate areas where projects may be lacking and hence the need to initiate projects in such specific areas.

In this chapter, the general features of underdevelopment of countries and the reasons for the need of accelerated economic development in these countries is briefly discussed. Also the type of development planning adopted by most of these countries and its merits are elaborated.

Economic Development and Underdevelopment

A clear understanding of the differences between economic underdevelopment and development is vital in the formulation and implementation of meaningful and effective programs to bring about necessary and desirable transformation. An understanding of the process of development and a knowledge of the ways and means of activating, controlling and maintaining the process are equally vital. This section is intended to aid in such understanding.

Differences Between Development and Underdevelopment

Development is a relative concept. Underdevelopment is a comparative and essentially negative concept. Underdeveloped countries are basically areas of radical scarcity where the inadequacy of the means of livelihood (social welfare) is the primary distinguishing feature. While more developed (also known as advanced or affluent) countries possess a number of common characteristics by which they can be positively identified (e.g., industrialized production systems; relatively high per capita gross national products; relatively high adult literacy; high per capita energy, calorie and protein consumption, high per capita income, etc.), the same cannot be said of underdeveloped countries. Such a positive identification of underdeveloped countries is impossible because it embraces diversified civilizations and societies, as well as the less affluent regions of the developed countries. In other words, underdevelopment is a notion that characterizes that which societies are not, i.e., developed, but does not characterize positively what in fact they are. Nevertheless, it is of interest to note that so many different observers and scholars have come up with very similar lists of characteristics of the underdeveloped countries, despite the fact that there are often vast differences in the political and cultural aspects, available information and record keeping of the various underdeveloped countries.

Characteristics of Underdeveloped Areas

Perhaps the most comprehensive list of characteristics of underdeveloped countries is given by Leibenstein (1957) who divided them into four major categories: economic, demographic and health, technological, and cultural and political characteristics. These characteristics are given below primarily as Leibenstein presented them with minor changes and updating.

Economic

a. General

1. A very high proportion of the population is in agriculture, usually 70 to 90 percent.

2. Evidence of considerable "disguised unemployment" and a lack of employment opportunities outside agriculture. "Absolute overpopulation" in agriculture, i.e., it would be possible to reduce the number of workers in agriculture and still obtain the same total output.

3. Very little capital per head.

4. Low income per capita and, as a consequence, existence is near the "subsistence" level. (Per capita income ranges from $48 to $192 per year.)

5. Practically zero savings for the large mass of the people as well as low capital formation--the rate of investment as a percentage of the national product, devoted to capital formation in the less developed countries is 5 to 6 percent as opposed to 12 to 15 percent or more in developed economies (Millikan, 1973). Whatever savings do exist are usually achieved by a landholding class whose values are not conducive to investment in industry or commerce.

6. The primary industries, that is, agriculture, forestry, and mining, are usually the residual employment categories.

7. The output in agriculture is made up mostly of cereals and primary raw materials, with relatively low output of protein foods. The reason for this is the conversion ratio between cereals and meat products; that is, if 1 acre of cereals produces a certain number of calories, it would take between 5 and 7 acres to produce the same number of calories if meat products were produced.

8. Major proportion of expenditures are on food and necessities.

9. Exports are mainly foodstuffs and raw materials (primary goods).

10. Low volume of trade per capita.

11. Poor credit and marketing facilities.

12. Poor housing.

13. Under-utilization of production factors.

b. Agriculture

1. Although there is low capitalization on the land, there is simultaneously an uneconomic use of whatever capital exists due to the small size of holdings and the existence of exceedingly small plots.

2. Exceedingly low agricultural technology with limited and primitive tools. The methods of production for the domestic market are generally old-fashioned and inefficient, resulting in little surplus for marketing. This is usually true irrespective of whether the cultivator owns the land, has tenancy rights, or is a sharecropper.

3. Low yields per unit area.

4. Even where there are big landowners, the openings for modernized agricultural production are limited by difficulties of transport and the absence of a sizable demand in the local market. It is significant that in many underdeveloped countries a modernized type of agriculture is confined to production for sale in foreign markets.

5. There is an inability of the small landholders and peasants to weather even a short-term crisis, and, as a consequence, attempts are made to get the highest possible yields from the soil, which leads to soil depletion.

6. There is a widespread prevalence of high indebtedness relative to assets and income.

7. A most pervasive aspect is a feeling of land hunger due to the exceedingly small size of holdings and small diversified plots. The reason for this is that holdings are continually subdivided as the population on the land increases.

Demographic

1. High fertility rates, usually above 40 per thousand.

2. High mortality rates and low expectation of life at birth.

3. Inadequate nutrition and dietary deficiencies.

4. Rudimentary hygiene, public health, and sanitation.

5. Rural overcrowding.

Cultural and Political

1. Rudimentary education and usually a high degree of illiteracy among most of the people (80 to 90 percent). This leads to inadequate manpower resources which is the key to development above all else (Albertson, 1972).

2. Extensive prevalence of child labor.

3. General weakness or absence of the middle class.

4. Inferiority of women's status and position.

5. Traditionally determined behavior and role for the bulk populace.

Technological and Miscellaneous

1. Inadequate manpower resources--both in quality and quantity.

2. Facilities for the training of technicians, engineers, and others needed as manpower resources for development are absent or inadequate at best.

3. Inadequate infrastructure.

4. Crude technology.

5. Dualism-existence of large metropolitan cities with modern civic amenities on the one hand and on the other, poor, unhygienic and backward rural areas. Similar dualism is found in the field of production and transport so that the hand loom exists side by side with the automatic loom, the bullock cart with the jet plane, and so on.

A close study of the foregoing characteristics would inevitably lead to the conclusion that underdeveloped countries are areas of acute scarcities and inadequacies. This particular impression, more than any elaborate theory, reveals the social aim and purpose for development, i.e., substitute scarcities and inadequacies with adequacy and plentifulness.

The Development Process

Understanding the development process requires a clear conceptualization of what is meant by development as well as a knowledge of the ends, the means, the measures, and the aims of development.

What is development? Development is basically a process of transformation, i.e., it is a process by which underdeveloped countries rid themselves of the foregoing negative characteristics and acquire certain characteristics of today's affluent nations: adequacy, plentifulness and more self-sufficiency.

The development process has been explained and analyzed in varied ways by different individuals at different times from different points of view. A comprehensive treatment of the development process based on a conceptual model called 'The Development Wheel' (Fig. II-1) is given by Albertson (1972). Using the Development Wheel, he explains and concludes that manpower is "...alpha and omega," "...the beginning and the end of the development process," and that "development is accomplished by man."

The wheel is explained by Albertson as follows:

> "The model shown in Fig. 1 depends upon man's knowledge and his motivation to use this knowledge to create and work through the necessary institutions. Man's motivation depends upon his values--both individual values and the values of the groups and the institutions that he creates and uses as vehicles. He uses the natural resources and the infrastructure to produce the goods, services, and information which can be used by man for consumption or for further development--in other words, for capital."

Among other things, an important aspect of Albertson's approach is the implicit suggestion that

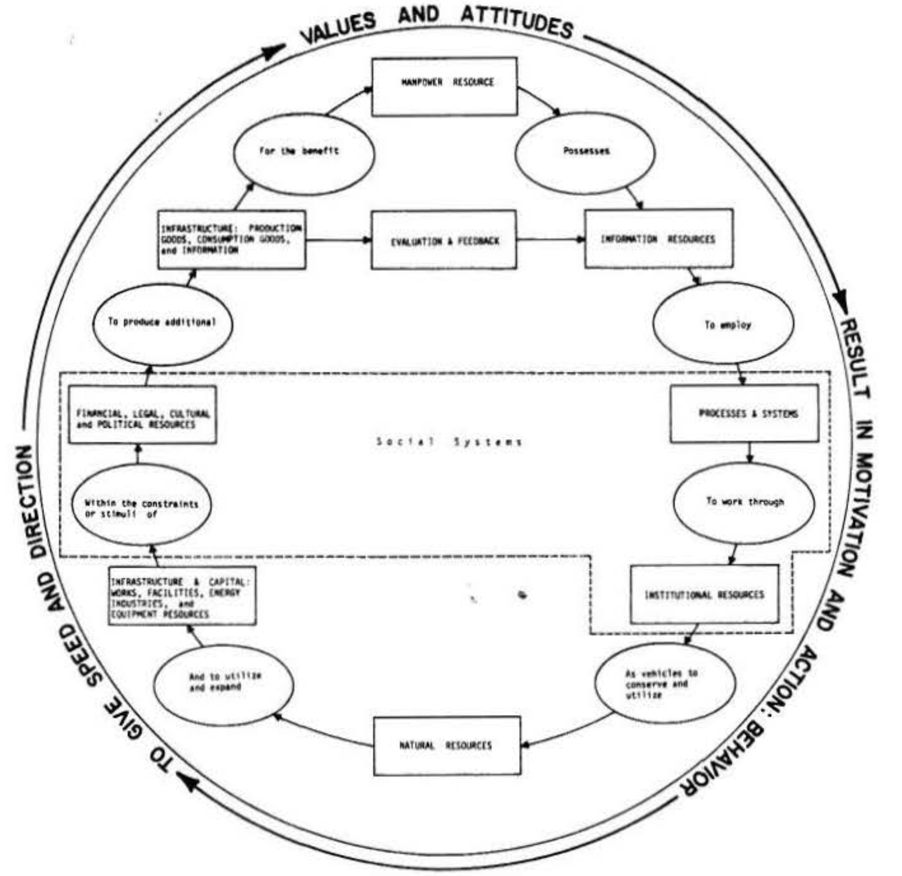

Fig. II-1. The Development Wheel, Illustrating the Development Process. (Adapted from Albertson, 1972).

development efforts should be exerted in order to satisfy the beneficiaries' needs and not to "keep up with the Joneses" as many would have it.

Development is often used synonymously with growth. Although this usage is generally accepted, there is a conceptual difference that has to be recognized for the benefit of the aid it gives in the role-identification of the different actors (individuals and institutions) involved in the development process. Economic growth means more output, and economic development implies both more output and changes in the technical and institutional arrangements by which it is produced. Stated in other words, development incorporates both the end (more output) and the means (changes in the technical and institutional arrangements by which it is produced). The degree of preoccupation of a country in either the end or the means depends on the prevailing circumstances and stage of development in which the country finds itself at a given point in time. Detailed analyses of the distinctions between growth and development are given by Kindleberger (1965) and Demas (1965).

<u>The ends of the development process</u>: In light of both the foregoing discussion and the aforementioned characteristics of the underdeveloped countries, development to such countries should mean a transformation of the socio-economic structure so that:

1. A desirable living standard is maintained.
2. The degree of dualism between sectors as well as regions is reduced.
3. Full and productive employment is maintained.
4. Adequate manpower resources (both in quality and quantity) are made available as needed at all times.
5. Adequate and flexible institutional (social, legal, political, administrative) structure is maintained.
6. Adequate infrastructure is maintained.
7. Subsistence production is eliminated and the national market is established for goods and services.
8. The share of manufacturing and services in the Gross National Product (GNP) is increased in response to the changing composition of demand.
9. The volume of interindustry transactions increases, mainly as a result of the growth of the manufacturing sector.
10. The ratio of imports to GNP falls in the long run (although the absolute value of imports may generally increase) and the composition of imports shifts from consumer to intermediate and capital goods.
11. The economy becomes not only more diversified but also more flexible and adaptable to social, political, and institutional changes.

The means of the development process: The development process, in the achievement of its purposes, involves either new combinations of existing factors at a given technical level or the introduction of technical innovation. Furtando (1964) defines as being fully developed at a given moment, those regions in which, in conditions of full employment of factors, it is possible to increase productivity (real production per capita) only by introducing technical innovations; and those regions whose productivity is increasing, or could be increased by the mere introduction of already known techniques, as displaying various degrees of underdevelopment. The growth of a developed economy is, then, a matter of accumulating new scientific knowledge and of advancing the technological application of such knowledge. On the other hand, the growth of underdeveloped economies for the most part is a matter of assimilating techniques already existing. Contrary to the school of thought that expertise and know-how could be imported analogous to cases where physical resources are inadequate, the past experience clearly shows that an adequate indigenous manpower resource is a prerequisite for sustained development to materialize.

The measure of economic development: Generally, the level of income and the rate of increase of income are used as the approximate measures of the state of and the rate of economic development (Kindleberger, 1965). Actually, indicators of economic development (Albertson, 1972) and their measurements are much more complex and wider in scope than Kindleberger suggests and than will be used in this study (growth of GNP over time). They should include all the variables (composed of the factors and actors) involved in the entire process. Economic development occurs when desirable changes take place over a given period of time in the separate, and in the sum results (both in quality and quantity) of activities carried out in the areas of industrial and commercial enterprises, administrative and legal institutions, manpower and physical (natural and man-made) resources, social (both private and community at large) amenities, etc. For the evaluation of economic development over a given period of time, simplifications and approximations of the measurements are made necessary due to the fact that a valuation system applicable to all the indicators is not available at the present time.

Economic growth (as distinct from economic development) occurs when key economic variables become larger from one period of time to the next in a systematic way. In this regard (Furtando, 1944), development consists basically of an increase in the flow of real income, i.e., an increase in the quantity of goods and services at the disposal of a given community per time period.

A more important characteristic of the developed economies (nations) which distinguishes them from the less developed ones, and from which most of the other economic distinctions logically follow, is the fact that they have exhibited over a period of several decades a capacity of sustained, built-in, and reasonably steady annual growth in per capita economic output amounting for, on the average, 2 to 3 percentage points per year (Millikan, 1973). Although it had been learned that during the past decade the less developed countries as a group have achieved an average per capita economic growth of nearly 2 percent (Millikan, 1973), this has not been self-sustained, this is evidenced by a significant portion of the resources (both capital and manpower) that have made this possible having been supplied by the developed nations in the form of some type of foreign aid.

The aims of national economic development: From the multitude of actual economic development plans adopted by some nations, as well as from the enormous scholastic works available, it is very clear that the aim of development is the achievement of regular long-term, built-in, sustained growth without external subsidy.

This is a very realistic and worthwhile aim for the less developed countries to have. While self-sustained, steady economic growth will not in itself necessarily bring with it adequate progress toward all the other goals that less developed countries seek in their development programs, it will facilitate achieving them. In the absence of such growth, significant progress toward most of these goals is impossible.

A significant manifestation of this aim as the key to the development issue is the fact that in 1961 the General Assembly of the United Nations resolved that the 1960's would be termed the "Development Decade." In this period, the world community would devote itself to the problem of generating a process of accelerated economic growth that could in time lift the world's less affluent (which constitutes two-thirds of the world's population) out of grinding poverty and provide the wherewithal for a marked improvement in the quality of life of the mass of the world's peoples. The quantitative target set was an annual average growth rate of the economic output or gross national product (GNP) of the less developed world of 5 percent (Millikan, 1973). On October 24, 1970, the twenty-fifth anniversary of the founding of the United Nations, the General Assembly voted unanimously to proclaim the 1970's "The Second International Development Decade" and to adopt the International Development Strategy which set the annual average rate of growth of GNP for the less developed countries to be at least 6 percent (U.N., 1970).

Development Policies and Strategies

Development strategies: While self-sustained growth is a common aim shared by most, if not all, developing nations, the policies and strategies that such countries adopt are diverse, depending on circumstances prevalent in the given country and on the stage of economic development that it has reached. Some of the priority strategies may be categorized as follows:

1. The allocation of investment resources among major economic sectors such as agriculture; manufacture of consumer goods; production of intermediate and capital production of intermediate and capital goods; improvement of infrastructure such as transportation, communication, and power. Incorrect allocation can sharply reduce the average productivity of capital.

2. The adoption of technologies appropriate to the country's resources base. For example, if, as in many less developed countries, capital is very scarce and labor is in abundant supply, productivity can be increased by adopting labor intensive and capital-saving technologies.

3. Research--for instance in agriculture, to develop new technologies particularly suited to the conditions prevailing in the country.

4. An appropriate balance between activities designed to replace imports with domestic production on the one hand and those intended to generate exports on the other.

5. Education, training, and the development of manpower resources, which is the moving force of development.

6. The creation, promotion, and improvement of institutions, public and private, whose smooth functioning is important to the development process.

7. The right balance between excessive governmental efforts to regulate, control, and manage economic activity and inadequate attention to such regulation and control in areas where it is important.

8. The provision of a framework for capital resources management, tax and fiscal policy and the control of markets that will maximize incentives to productivity improvements.

Obstacles to economic development: The selection and adoption of anyone or groups of the various measures to promote sustained economic growth categorized above, as well as the setting of priority among them, is the responsibility of the government of a country. Of course, the adoption or even a pledge of commitment for concentrated effort for implementation of development policies and strategies, at best, could be only the beginning to the long and arduous process of economic development which is jammed full of obstacles and surprises. Some of the potential obstacles to economic development of underdeveloped countries published by the United Nations in 1951 include (U.N., 1951): lack of adequate manpower resource; lack of an experimental outlook encouraged by education; prevalence of other worldly philosophies and a high preference for leisure; existence of avenues to social prestige easier than via achievement; prevalence of motivations and values that inhibit rather than induce and accelerate development; lack of enterprise and entrepreneurship; absence of a broadly based credit structure; prevalence of foreign owned enterprises operating under terms that are not favorable to the local economy; weak or arbitrary government; extended families; defect of the law; legal or customary barriers to innovation; lack of information; low social mobility and horizontal resource mobility; monopolies; concentration of power into too few hands; deficient leadership; as well as many others.

A desire to eliminate or minimize the effects of these obstacles, among other reasons to be discussed in the following section, is one of the primary reasons for the almost universal adoption of development planning by the less developed countries.

Planning for National Economic Development

Among other things, planning for National Economic Development (NED) is the task of government. The purpose of planning is succinctly stated by Colm and Gieger (1965): "...the purpose of planning is to enable governments to deliberately influence economic processes in order to supplement, reinforce, support, and guide the market process of decision making and activity. More specifically, planning seeks directly or indirectly to influence those factors believed to determine the rate and direction of development." In this section the need for planning, the types of plans and their component parts are presented.

The Need for Planning for NED

The major reasons why planning for national economic development is considered to be necessary are changing trends and preference of government intervention over 'laissez-faire' economy.

Changing trends: Planning for economic policy, and particularly planning for national economic development by government, is increasingly gaining preference over the 'laissez-faire' doctrine.[1] In the past, except in the socialist countries, planning for economic policy was a temporary exercise launched as a remedial measure in times of war, depression, or crises of one kind or another that involves some economic bottlenecks. The increased tendency towards planned economic policy (development) as opposed to the 'laissez-faire' doctrine are based, as explained by Tinbergen (1967) and summarized here, on three major concepts, which themselves reflect a change in human conceptions:

1. The tendency of being more and more conscientious--the conscious introduction of looking ahead

2. The growing awareness of the interconnection between various economic factors--resulting in the new effort to integrate different parts of economic policy.

3. The changing tendency in views about the aims of state intervention, i.e., whereas state intervention in the past was aimed at alleviating economic bottlenecks or crises, it is now increasingly regarded as an activity that fits closely into the whole economic development process and is aimed far more at bringing about sound economic development than at curing economic ills.

These three concepts yield the three chief elements of planning for national economic development--looking ahead (predicting or forecasting), coordination, and attainment of desired aim.

The foregoing concepts, especially the third (in light of effecting accelerated economic growth instead of letting the economic system take its natural pace, and not so much that of the acceptance of an ideological principle of state ownership of means of production), provide the major reasons for the almost universal acceptance of central (state) development planning in the less developed countries. In other words, central planning is adopted by the developing countries not as a result of endorsing the ideology and joining the camp which believes that "égalité" would be best accomplished if the means of production is owned by the state (and hence it should do the planning). On the contrary, it is rather because of the growing awareness of the fact that intervention and control is best effected by the state rather than the market mechanism in order to bring the aim of accelerated economic growth--i.e., the improved welfare of the society. This leads into a new arena where the case for and against planned economic development is debated primarily by economists.

Preference among market control and state intervention: Currently, there does not appear to be anyone who believes in absolute 'laissez-faire' (market controlled economy) since most economists who are proponents of the market controlled economy acknowledge

[1] Laissez-faire: doctrine of nonintervention by government.

several departures from the competitive market norms which justify public intervention. Broadly, these include the following:[2]

1. To set, modify and enforce rules under which individuals and society must operate.

2. Direct intervention in the development and management of public and merit goods where the exclusion of individuals from consumption of goods and service due to consumption by others is not applicable (e.g. public goods, nonmarketable goods, etc.).

3. Intervention in order to correct certain failures in the market mechanism such as:

   a. product and factor indivisibilities
   b. externalities
   c. monopolies
   d. extreme scarcity of goods.

Thus, the proponents of market controlled economic policy say that, except for the foregoing areas, the control should be left to the market. Although this issue has been a subject of controversy between the proponents of the two principles (laissez-faire versus planned economic policy) and remains an unsettled question, a detailed comparative analysis will not be made here since in situations where accelerated growth is the aim (which means intervention is necessary), the extremely fragile assumptions that underlie the competitive market model simply will not exist--besides, the case for planned development has already been made on more realistic and fundamental grounds.

Nevertheless, a brief note on the major points against each policy is in order for the sake of completeness of presentation. For further details see Bator (1958) and Lewis (1961). The major arguments against completely centrally planned and coordinated policy are its inflexibility since revision involves complex relations; its incapability to quick response and adjustment to changes; its liability of imperfect fulfillment due to its inflexibility and the realism of uncertainty in such decision making; mistakes are bound to be costly since they would inflict a chain of wrong decisions.

The major arguments against a market controlled economy are its inadequacy for fair income distribution, for handling of foreign trade, for coping with major changes (slow effect to speed or slow mobility of resource in response to changes); and its being unstable (which is the main reason for constant state intervention in western markets today) and wasteful. The most important argument against the market control policy is the fact that the merits of the market depend on the existence of perfect competition, and that perfect competition is rare if not absent. Lewis (1961) asserts that nothing in the market mechanism establishes or maintains competition and that only state action can assure competition. Indeed, the market cannot function adequately without positive support from the state.

Thus, the point that should be clearly understood is that the choice, as learned from past and present situations, is not one of an either/or case, but that of a mix. The area, scope and level of state intervention (planned development) may vary from one country to another. The less developed the economy, the higher the desired rate of development, and the less competitive the market mechanism; consequently, the higher the level, the wider and deeper the scope, and the larger the area of state intervention required--for a policy of nonintervention here would be inadequate. In other words, the need for the adoption of a planned development policy is dependent on the degree of underdevelopment of a country.

Types of Planning

Depending on the criterion used, planning could be classified into several types. According to the institutional arrangement, planning could be classified into centralized (planning by government) and decentralized. There have been cases, although rare, where departmental planning (planning done by individual departments independently--without a central organ to coordinate their activities) are practiced.

In character, plans could be classified into indicative and directive. Indicative planning is conducted for the purpose of pointing out the desired direction for further advancement and implementation is primarily based on persuasion. Implementation is made imperative by the state in the case of directive planning.

In scope, planning could be multisectoral, sectoral, or functional (U.S. National Water Commission, 1972). Multisectoral planning is a comprehensive coordinated planning for all sectors of public endeavor. Sectoral planning is integrated planning for all functions (purposes) within one sector, such as water resources. Functional planning is planning to meet a specific need within a sector, such as flood control or the like.

The major and most common classification of planning is the one based on the time span covered by the plan. There are three broad categories in which plans are usually classified in terms of their duration. These are known as perspective or long-term, medium-term, and short-term plans. Perspective plans cover a span of one or two decades. These plans depict the general course to be taken by the national economy. Medium-term plans extend anywhere from 4 to 6 years. Although a span of 5 years is the duration adopted by a large number of developing countries for their medium-term plans, the precise length is often determined by administrative and political requirements (such as terms of elected executives and legislators) in conjunction with making the necessary allowance for the maturation of major projects. The short-term plans include plans of 3, 2 and/or 1 year duration. Of these, the annual plans, as reflected by the government budgets over the fiscal year of a country, are the most detailed and popular in use.

A development plan of a country should include each of the three major categories depending upon the stage of plan formulation and type of influence the particular program is to cause on the overall economy. Measures aimed at counteracting influences on the country's economy caused by unforeseen incidental matters, as well as those aimed at adjusting to conditions caused by unpredictable fluctuations, are to be covered in the short-term plans of annual duration. On the other hand, undertakings that cause long-term influence on the economy due to factors such as long-term investments or far-reaching institutional changes are covered in the long-term or perspective plans. Almost

[2]For detailed discussion of these failures see Friedman (1962), Herber (1968), and Bator (1958).

all major water resources development projects belong to the latter category since they involve large amounts of expenditures over long periods of time (Hall and Dracup, 1970). It is desirable for planning in a country to cover each of the main categories, for it would then be possible to build up detailed projects within a suitable framework.

Major Components of Planning for NED

The process of development planning involves a large number of activities which may be distinguished and carried out as logical phases or steps (Colm and Geiger, 1965; Timbergen, 1964). For convenience these activities are identified in this study as: goal identification and specification, inventory of resources, program formulation, and provision for implementation. These activities are not necessarily to be carried out in chronological order.

Goal identification and specification: This involves the definition of the purpose(s) for which development is being undertaken--which is usually done in three levels of specificity.

The first level is a statement of the general objective of the plan. For example, the purpose of the plan may be to raise the standard of living, to eliminate dependency on foreign assistance, to diversify the economy, to improve defense capabilities, or a combination of these and other objectives similar in nature.

At the next level, these objectives are expressed in terms of specific goals such as increases in production, savings, investment, consumption, foreign trade and other aggregative variables that are felt to be needed to be used as instruments (strategies) that help accomplish the general objectives of the plan.

Finally, targets are established. Here, precise measures and quantitative levels that each sector of the economy must achieve are specified. Of course all three levels must be related to a time frame for their accomplishment.

Inventory of resources: This is determination of resource capabilities available for achieving the specific goals and targets of the development plan. Resources include the necessary production inputs as well as the capital required to utilize existing material and human resources and to develop additional ones.

Program formulation: This is the central activity around which all the others revolve. It involves the formulation of specific programs within the general plan framework. Programs embody final decisions about targets, setting of priorities, selection of individual investment projects, and timing within particular sectors of the economy; and also specific regions within the country as well as related specific matters.

Each program includes not only a description of specific targets to be achieved, but also an inventory of resource requirements and the phasing of the program over time. Although this has been missing in most existing development plans, ideally each program should be refined to the point where it lists the individual projects which must be undertaken as well as their phasing over time. In addition, the program should specify the means whereby the resources are mobilized for achieving the goals of the program. This latter part overlaps with, and very much depends upon, decisions to be made in the next phase of the planning process.

Provision for implementation: The necessary arrangements for implementation of the plan are too often neglected entirely or are inadequate in today's development planning. These arrangements include (Colm and Geiger, 1965): the organization of the planning function and its administrative relationships with the chief executive, the legislature, and the policymaking and operating departments of the government; the assignment of responsibilities for carrying out the component programs of the plan; the relationship of the plan to the national budget; the roles of the fiscal and monetary authorities; the provisions for progress reporting and evaluation; and the selection and training of planning personnel. This phase should also include the selection of the means whereby resources can be mobilized to achieve the specified goals and targets.

The task of the private and public sectors, as well as the instruments to be used by the government in order to induce all concerned to carry out the plan, must be scrupulously studied and decided upon. A government has at its disposal various types of policies and measures for directly or indirectly bringing about the desired development. These include direct public investment; making public funds available in various ways to the private sector; different kinds of aid obtained from foreign governments and international organizations; encouragement of private foreign investments; fiscal and monetary policies to limit consumption, augment savings, and stimulate and channel indigenous private investment; and other instruments at the disposal of the national government (Clifford and Osmond, 1971). The particular combination of means (measures) that the government selects depends on the particular needs, administrative capabilities and limitations, and past experiences of the country concerned.

The planning process is not one of carrying the activities described in a strict chronological order; rather, it is an iterative process involving the modification and updating of conclusions and results derived at the end of each step in the light of knowledge acquired and information gathered in carrying out subsequent steps. All figures should be revised when new data become available.

The Place of Project Selection and Timing

In this study "project selection and timing" refers to the decision-making process of determining which projects should actually be implemented and when. The criteria that are to be used in such decision making will be elaborated in Chapter IV.

Another aspect to be specified is that a clear distinction is made between "project selection and timing" and "project evaluation." The first expression is understood to mean what is stated above, while "project evaluation" is associated with the decision-making process usually carried out for the purpose of determining economic and financial feasibility of a project. Thus, project evaluation is carried out for the purpose of determining the economic efficiency of individual projects as investment entities, while project selection and timing is performed for the purpose of determining "the best mix of projects"[3] that are available to meet plan objectives and sectoral goals and targets during a specific time schedule.

Project evaluation is done at the project formulation level while project selection and timing is done at the program formulation phase of the planning process for the entire economy.

[3] For more details refer to Chapter IV

Chapter III
SURVEY OF PRESENT PRACTICES OF PROJECT SELECTION AND TIMING

A survey of the available literature in the general area of project analysis[1] would invariably lead to the deduction that a tremendous amount of work is done with respect to project evaluation, while the work done with respect to project selection is meager and incomplete. Some avoid the issue by stating that the selection of projects is outside their scope of work while others give indications of implicit use of the evaluation methods for project selection as well. In this chapter, an assessment is made of the major works related to selection and timing of projects in general as well as their relevance to, and necessary improvements to make them applicable to the selection and timing of water resources projects intended to promote accelerated, yet balanced[2] national economic growth in a centrally planned and coordinated framework. For convenience the works will be subgrouped under the following categories: guidelines and methodologies used by the federal agencies of the United States of America, guidelines and manuals recommended for use by international agencies and organizations, and recent developments and recommendations from academic and research institutions. Incidentally, it may be well to point out at the outset that the relevance to and the adequacy of the various methodologies found in the foregoing categories, for their application for the selection and timing of water resources projects, improves as one moves down the list.

Federal Agencies of the United States of America (U.S.A.)

Since the economy of the U.S.A. is primarily based on a competitive market whose development is to be controlled by the relevant market forces, such as consumer sovereignty and the laws of supply and demand, the areas where the federal government engages itself in direct investment and management are very limited. In fact, except in times of economic crisis or war, it would not be a gross mistake to state that the federal government is limited to the bare minimum areas of state intervention accepted by the proponents of 'laissez-faire' economic policy.[3] Consequently, there has not been call for project selection, and hence for the methodology, to achieve balanced and coordinated national economic development.

On the other hand, there seem to be developments that suggest changing trends toward planned and coordinated development at least in the area of water and related land resources. The primary means used by the United States Government to achieve its economic objectives is through control effected by the appropriation mechanism of federal funds. Since the federal agencies, and the projects for which they seek federal funding, are numerous (and yet the federal agency that is charged with the responsibility of evaluating the projects is only one, Bureau of the Budget) it has been necessary to develop a standard method for the evaluation of projects by the various federal agencies. This, among other reasons,[4] has resulted in the formulation and adoption (into law) of the Federal Register Volume 38, No. 174, Part III, in September 1973 which has been in effect since October 25, 1973. This document establishes the principles and standards for planning water and related land resources (U.S. Water Resources Council, 1973). The entire document, when completed, is to be composed of three major component parts: Principles, Standards, and Procedures for water and related land resources planning.

The Principles reflect major public policy and public investment theory. They provide "the broad policy framework for planning activities and include the conceptual basis for planning." The Standards present the best available techniques for the application of Principles. They provide for "uniformity and consistency in comparing, measuring, and judging beneficial and adverse effects of alternative plans." The Procedures consist of detailed methods for the application of the Principles and Standards. They provide "more detailed methods for carrying out the various levels of planning activities, including the selection of objectives, the measurement of beneficial and adverse effects, and the comparison of alternative plans for action. Procedures are developed within the framework of Principles and the uniformity of Standards but will vary with the level of planning, the type of program, and the state-of-the-art of planning."

According to the foregoing description of the major parts of the document, methodology for the selection and timing of water resources projects should be included in the Procedures which is yet to be developed and approved.[5] The document published in June 1969 (U.S. Water Resources Council, 1969), which actually is a preliminary draft developed by the Special Task Force on evaluation procedures, covers in detail concepts and techniques of evaluating and measuring benefits and costs of water resources projects. However, it does not give any specific methodology for either the selection or the timing of projects.

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[1] Project analysis: includes and is not limited to the processes of project inception, formulation, evaluation, selection, timing, and impact assessment.

[2] Balanced growth: The situation where simultaneous investment in a number of projects (sectors) (the so-called horizontal dependence in consumption demand) is planned and coordinated by the government so that thus generated income will create inducement for further investment ('supply creates its own demand'). The government also monitors the expansion of the supply of all outputs in accordance to that of the demand for them (the so-called vertical structure of products) so that bottlenecks may not hold back the rate of growth (Mathur, 1971).

[3] Refer to Chapter II, p. 21.

[4] For detailed account of the long-term developments that took place in the creation and evolution of federal guidelines for water resources project evaluation refer to Caulfield (1973).

[5] It is accurately noted in the "Guidelines for Implementing Principles and Standards for Multiobjective Planning of Water Resources" (U.S. Bureau of Reclamation, December 1972) that: "The approach to be followed in selecting plans or alternative plans for large areas is not specifically addressed in the Principles and Standards."

In the 1960's, in accord with procedures of the "Policy, Program and Budgets System (PPBS)," analyses of priorities for project funding within a budgetary constraint were made within the Executive Branch. The Corps of Engineers, for example, made intensive analyses in this regard. More recently, the Water Resources Council has established an administrative system for "prioritizing" data collection, planning efforts, and project selection leading to presentation of priorities to the Office of Management and Budget. These efforts are directed toward the same concerns of this paper, but they have not yet advanced very far in terms of use of rigorous analytical tools in decision making.[6]

Concern with this matter is reflected in Sec. 201 (b) (3) of the Water Resources Planning Act of 1965 (P.L. 89-80) which provides that Federal-State river basin commissions established under the terms of the Act shall "recommend long-range schedules of priorities for the collection and analyses of basic data and for investigation, planning and construction of projects (U.S. Congress, 1965).

The need for a methodology for the selection of projects and plans is strongly expressed in a more recent report, "Guidelines for Implementing Principles and Standards for Multiobjective Planning of Water Resources," that was developed by a multiagency task force under the leadership of the Bureau of Reclamation (U.S. Bureau of Reclamation, 1972). Here, "the selection of a recommended plan of action" is recognized as "the culmination of the plan formulation process" and a rather detailed conceptualization is presented on the selection process. While it is suggested that plans be selected on the basis of maximizing net national economic development benefits, hope is expressed that employment of better methodologies will be possible as modeling procedures using systems analysis and operations research techniques are developed. It is the express hope of this researcher that the result of the present study will be a positive contribution in this direction.

Recommendations by International Organizations and Agencies

Manuals and guidelines in the general area of project analysis have been prepared by three major organizations who play leading roles in international development efforts. These are the United Nations Industrial Development Organization (UNIDO), the Organization for Economic Cooperation and Development (OECD), and the International Bank for Reconstruction and Development (IBRD).

The World Bank (IBRD) recommends and uses the "internal rate of return" as the measure of performance for economic and financial analysis as well as for the selection (ranking) of projects from among possible choices. The formal evaluation criterion for the "internal rate of return" measure of project worth is to accept all projects having an internal rate of return equal to or greater than the opportunity cost of capital and projects are ranked in order of the value of their internal rate of return (Gittinger, 1972).

The UNIDO Guidelines (U.N., 1972) and the OECD Manual (OECD, 1972) are concerned in the main, with industrial projects; yet the principles are said to be equally applicable to all investment undertakings. Although the approaches given by the two organizations have distinct differing points (most of which are not relevant to the theme of this paper), they may be considered similar with respect to matters significant to this study. Both recommend the use of net present value as the correct criterion in judging projects. They both recommend the use of shadow prices instead of market prices for the evaluation of social benefits and costs. The one difference that should be mentioned is that they use different numéraire (measure). However, this does not make any difference to the outcome of project evaluation (Dasgupta, 1972).

The UNIDO Guidelines recommends measuring benefits and costs in terms of consumption, while the OECD uses investment (expressed in free foreign exchange terms) as the unit of measurement. Thus in the UNIDO approach aggregate net benefits expressed in terms of consumption are discounted whereas in the OECD approach the net benefits expressed in terms of investable resources are discounted. The choice as to which numéraire to use is a matter of convenience. What is important is that, as Dasgupta's rather lengthy and thorough analysis of the differences between the two approaches concludes: "...it ought to make no difference to one's judgment about the desirability of a project." Nevertheless, both approaches recommend the use of net present worth as the basis for project evaluation. The formal criterion in these approaches is to accept all projects which have positive net present worth.

The UNIDO Guidelines does not recommend a specific procedure for project selection, yet the procedure recommended for project evaluation coupled with the assumed point of view of the decision maker (a firm's point of view) would implicitly lead to a similar procedure as that recommended by the OECD Manual. The OECD Manual recommends that projects be selected and ranked according to their profitability. Although it prefers to use a so-called 'profitability ratio' (in case of limited borrowing capacity), it recognizes the net present worth of a project as an important measure of profitability.

All the foregoing procedures, although they may differ among themselves in some specific point(s) of detailed nature, have one feature of major importance in common. Although not always clearly specified, they all have "maximization of profit" as the primary, if not the only, objective to be adhered to in selecting projects.

It is apparent, therefore, that the decision is being made from a firm's point of view in a competitive market framework.

The three criteria often used in project evaluation exercises are: benefit cost ratio greater than or equal to unity ($B/C \geq 1$), positive net present worth ($NPW > 0$), internal rate of return greater than or equal to the social opportunity cost of capital ($r \geq i$). All these criteria are criteria that indicate the profitability of a project. Thus, they show the economic efficiency of the given project. In plain language, the satisfaction of any one of the foregoing efficiency criteria by a project means that it will produce benefits equal to or greater than the cost of the project. Thus, satisfaction of such criteria by a project should mean just and only that it is economically feasible. Ranking or authorization of projects for implementation may be based on such efficiency criteria only in very special cases--such as when projects are authorized

[6] Interview with Professor Henry P. Caulfield, Jr., of Colorado State University, July 3, 1974.

in isolation and/or when there is no budgetary constraint and the repayment capability of a project is the only concern. Ranking or selecting water resources projects for their implementation in order to promote accelerated and balanced national economic development in the less developed countries solely on the basis of economic efficiency criteria is inappropriate, "inter alia," for the following reasons:

1. Water resources development in less developed countries in this era involves multipurpose means for achieving multiple objectives of various levels. This is a much more complex situation than that of a firm concerned with a single enterprise of a given type of output.

2. Water resources development in almost all developing countries is a public (state) undertaking, hence the selection of projects cannot be done solely from the private investors' point of view, who selects projects only according to rates of profit.

3. A public program in a given sector or subsector will consist of some selection of individual projects from among a large number of possible projects. This entails possible incompatibilities and interdependencies among projects which cannot be handled with a single efficiency criterion alone.

4. In a centrally planned and coordinated economy where the doctrine of balanced growth is adopted, the state intervention goes as far as making simultaneous investments in numerous projects and sectors as well as monitoring the rate of growth of supply (project outputs) in accordance with the demands for them. Therefore, not only is it inappropriate to rank projects according to a single efficiency criterion (which is what happens when one accepts projects up to a specified cut-off point as the present recommendations hold), but it is wrong to speak of ranking of projects, per se. The truth of the matter is that one can only select projects, and select not only to maximize profit, but select also in compliance to all relevant considerations--in this case, a priori set levels of project outputs which are projected demands necessary for a balanced growth.

5. Availability of funds limit the volume of public expenditure which create budgetary constraints and do not allow building every project that meets efficiency criteria.

When all these considerations are taken together, it is evident that the pure efficiency criterion can neither be adequate nor dominant in the process of selection and timing of projects to formulate an optimum water resources development program that will promote national economic development.

It should not be misunderstood that an abandonment of the use of efficiency criteria in project selection is being recommended. On the contrary, because of the innate insensitivity of government (in contrast to a firm) to the lures of profit and the threats of bankruptcy, economic efficiency must, and does, have a special role which warrants due treatment, but it is within limits established by all the pertinent factors that depict the situation. It is in recognition of its relative importance that the researcher considers and recommends that the satisfaction of economic efficiency criteria by a project (economic feasibility of a project) be a necessary condition in the selection process. The sufficient condition is the meeting of the other constraints that depict the pertinent dimensions of the decision space.[7] Developing a mathematical decision model based on the foregoing concept, using systems analysis and operations research techniques as the nucleus of the methodology to be developed in this paper, is the primary challenge in this study.

Developments in Research and Academic Institutions

Although there have been some publications in areas other[8] than resource allocation and capital budgeting, the question of selection and timing of projects has, in the main, been most extensively studied in these two major areas. It was Lorie and Savage who pioneered in articulating the major dimensions of capital budgeting problems (since known by the pseudonym "the Lorie-Savage problems") (Lorie and Savage, 1955). This marked the beginning of a vigorous and intensive work which resulted in the much more complete works of Weingartner (1963), Oakford (1970), and Duff (1971). Leaving the details and sequence of improvements brought about by these and other scholars in the field, the major aspects relevant to the topic of the current study are as follows.

The major positive features that the literature on capital budgeting offer and which constitute a better reflection of realism, in contrast to the manuals and guidelines discussed in the previous section, are:

1. Recognition of capital rationing and project selection as the rule, rather than the exception, contrary to the usual disregard on the grounds that rationing ought not to exist when firms behave rationally, which in turn is a basic assumption in the theory of firm and market behavior (Weingartner, 1966).

2. Provide for capital constraint considerations.

3. Provide techniques for handling project interrelationships.

Even though these are improvements of paramount importance, selection and timing models presented in the capital budgeting literature do not reflect in full the aspects of the real world. In particular, they do not provide techniques for handling considerations stipulated under numbers 1 and 4 in the foregoing section. These are legitimate considerations that make a real difference in the outcome of the selection and timing of water resources projects and even more so in situations laid out in Chapter II.

The mathematical model to be developed as part of the methodology for selection and timing of water resources projects worked out in this paper includes provisions to reflect these important aspects.

[7] For further details of this aspect, refer to Chapter IV.

[8] Examples of such works include: Steiner, 1959; Reiter, 1963; Butcher et al., 1969; Morin and Esogbue, 1971.

Chapter IV
METHODOLOGY FOR THE SELECTION AND TIMING OF WATER RESOURCES PROJECTS

"Planning by itself is a fruitless activity: The purposes of planning are to assure the proper choice of projects and to achieve their efficient implementation." (Solomon, 1970)

Making the proper choice of projects and deciding when to implement them is the concern of this paper. Such decisions are important and critical in certain respects. It is even more so when the selection and timing for implementation involves water resources projects. The relatively highly irreversible nature of decisions to implement water resources projects, coupled with the large magnitude of necessary resource inputs, and hence the implicit costliness of a wrong decision, are but a few of the many reasons why the selection and timing of water resources projects for their implementation is one of the most important and critical aspects of planning for national economic development.

Therefore, such decisions should be based on sound rationale and be assisted by systematic and rigorous analytical procedures augmented by informed judgment.

Rationale, Objectives, and Criteria

Rationale for Project Selection

The rationale for project selection must be the optimal achievement of "a priori" specified ends. Water resources projects should not be implemented for their own sake and they should not be considered an end in themselves; rather, they are part of a series of chains of means used to achieve a wider range of socio-economic objectives.

In a system of interrelated sectors, activities in each sector should be directed and monitored in order to fulfill the share of the particular sector. Sectors are further disaggregated into subsectors and projects. Accordingly, the national economic development objectives must be specified as targets for the sectors and subsectors to meet in a given time framework. Thus projects must be implemented in order to achieve such targets with the optimal resource allocation directives--efficiently and economically, and their selection must be based on their effective estimated contribution to the targets.

Rationale for Timing

The outputs and services of water resources projects, by and large, are intermediate commodities needed by other sectors as their inputs. This means, for sectors that use the outputs of goods and services of water resources projects as inputs to meet their respective targets by a given point in time, the water resources projects that produce the needed inputs should already be in existence and operating. Therefore, implementation of water resources projects should be timed such that it is completed by the beginning of the respective overall plan period.

Objectives of Water Resources Development

The development, exploitation, and maintenance of the resources of a nation have the aims and goals stated in Chapter II as their objectives--in a nutshell, promote the quality of life (national welfare). The objectives of water resources development, however stated, are rooted in these overall goals. Although a national development plan may list several overall objectives in varied specificities, the objectives of water resources development can be grouped into three major ones:

1. To enhance national economic development (NED)--mainly achieved by increasing the value of the nation's outputs of goods and services and improving national economic efficiency.

2. To enhance social well-being--mainly by providing and maintaining such social amenities as security, health, education, employment, etc.

3. To enhance the quality of the environment--mainly by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

This grouping may be considered as a compromise version of those stipulated by Senate Document 97 (U.S. Water Resources Council, 1962) and the Federal Register (U.S. Water Resources Council, 1973) which in turn is a further articulation and refinement of the former.

Because the purpose of this paper is to develop a methodology for the selection and timing of water resources projects for national economic development, the last two objectives are not considered further, except to point out the following. Mainly because of the fact that it had been impossible so far to have a valuation system of the benefits and costs (mainly the benefits) in a quantitative form commensurate with that used for the valuation of the conventional primary objective, economic development, the evaluation of projects and programs with respect to these objectives could not be carried out by the use of rigorous analytical procedures. Such goals are traditionally assumed to be achieved through measures such as taxation, subsidies, special isolated projects and programs, etc. This is an area where research is overdue. Hopefully, the work presently being undertaken by the Water Resources Centers of the Thirteen Western States will have positive results in this respect.

The National Economic Development (NED) Objective

"The national economic development objective is enhanced by increasing the value of the nation's output of goods and services and improving national economic efficiency." (U. S. Water Resources Council, 1973)

From this statement, it is clear that the objective of NED can be translated into measurable quantitative indicators, namely:

1. Value of output of goods and services.

2. Economic efficiency.

Implementation of water resources projects results in increased production of goods and services which can be measured in terms of their values. Measurements of both of the foregoing components of the NED objective are well known (U. S. Water Resources Council, 1973; Young and Gray, 1972; U. N., 1972; Gittinger, 1972).

Gross national product (GNP), expressed in market values, is the measure customarily used to express the current or projected national outputs of goods and services. Furthermore, GNP is the aggregate sum of market values of outputs of goods and services of individual sectors and industries of the whole economy. With respect to the water resources sector, the sectoral component of the GNP is in turn the aggregate sum of the values of the outputs of goods and/or services of individual water resources projects. For convenience the water resources sector may be disaggregated into subsectors (industries--in input-output analysis parlance) according to the following traditional water resources project purposes and treated as a sector of the national economy:

1. Municipal, domestic, and industrial (M&I) water supply.

2. Melioration--irrigation, drainage and reclamation.

3. Hydroelectric power.

4. Navigation--inland waterways and appurtenances.

5. River regulation--flood control, low flow augmentation.

6. Recreation and conservation.

The Standard Industrial Classification Manual (U.S. Bureau of the Budget, 1967) does not distinguish or provide for a separate water resources division (sector) composed of the operating, administrative and auxiliary establishments engaged in the production of outputs of goods and services by projects and programs involving water and related resources. The rather obvious use to be made of and benefits to be gained from such classification and incorporation of the same in the national record keeping and accounting system justify its adoption.

The foregoing classification not only complies with the general principles for classification given in the manual, but also satisfies fully the purposes of such classification (U. S. Bureau of the Budget, 1967):

> "The Standard Industrial Classification was for use in the classification of establishments by type of activity in which engaged: for purposes of facilitating the collection, tabulation, presentation and analysis of data relating to establishments: and for promoting uniformity and comparability in the presentation of statistical data collected by various agencies...".

Furthermore, such a provision would facilitate better water and related resources development planning and balanced growth. It facilitates the maintenance and accurate tracing of objectives (depending on the planning strategy) through hierarchical levels of planning, thus avoiding what McKean (1958) termed as an "inherent danger" of suboptimization--disaggregated analysis of a large system. It enables more direct and reliable assessment of current and future demands for water resources outputs. It also enables relatively earlier and easier detection of bottlenecks providing ample time to carry out the necessary corrective measure. Thus, the creation of a separate water resources sector is desirable in more ways than one; it provides a readily available information source, facilitates better planning, enables prompt and appropriate action based on informed judgment for better end results, all of which are for economic development.

Getting back to the main point of this section, GNP, the aggregate sum of the market value of outputs of goods and services of all the sectors of the economy, both public and private, is the measure adopted to express the values of the nations' outputs of goods and services and hence serve as the indicator of the first component of the NED objective. The indicator to the second component of the NED objective, as well as the exact form of the criteria for the selection of water resources projects, is elaborated in the next section.

The NED objective is formally expressed as a percentage rate increase of GNP over specified plan periods. This is further broken down into target levels or increases in values of sectoral outputs of goods and services and expressed in scalar quantities for operational purposes.

Criteria for the Selection of Water Resources Projects

Objectives stated in the terms given in Chapter II may become meaningless or confusing and certainly are not operational. They become meaningful and operational only when expressed as indicators in more specific and quantitative forms. For purposes of selecting and timing of projects for their implementation via rigorous analytical procedures of systems analysis, objectives have to be further specified and expressed in terms of criteria.

The methodology proposed in this paper incorporates a series of procedures as well as a mathematical model. The mathematical model is the analytical tool by which the actual selection of the projects for the optimal achievement of the NED objectives is carried out. The usefulness of a mathematical model is highly dependent upon the degree of approximation of the real case by the model. The more aspects and phenomena (interrelationship) of the actual case depicted by a model the better it represents the case under consideration and the more useful it is for purposes of study, analysis and subsequent inferences to be made. In general, mathematical models have four major components (Au and Stelson, 1969).

1. A set of decision variables.

2. A set of constraints.

3. An objective function.

4. An optimal solution.

The first three elements are the vital means through which the analyst must try to depict the real situation during the problem formulation and model building. In this regard, the most effective use of these elements requires a good know-how of both the art and the science of systems engineering as well as a thorough knowledge of the system--physical or otherwise. Thus in determining the criteria for the selection of projects, the appropriate relationship between the NED objectives and the means of the physical system (water resources projects) should be depicted by the major elements of the selection model.

Criteria are operational means of judging preference of alternative choices in light of a given objective(s). They may also be seen as approximations to measure objectives. Yet, the fact that the NED objective is translated into two indicators may be a potential problem of a conceptual nature in the use of a mathematical optimizing model. According to the "Zeroth law of Operations Research" (Morel-Seytoux, 1973), one can optimize only one objective at a time. In other words, one cannot maximize benefits and minimize costs simultaneously. An important point of relevance that needs to be mentióned here and must be kept in mind is that although maximization of economic efficiency does invariably lead to maximization of outputs and services, in circumstances where the policy of balanced growth is the operating framework, it is not the maximization of the aggregate GNP that is sought as much as it is that of the attainment of a priori identified and specified levels of outputs and services.

Furthermore, it was resolved earlier (Chapter III) that the economic feasibility of a project (satisfaction of economic efficiency criteria by a project) be a necessary condition in the selection of projects. "Necessary" and "sufficiency" shall be understood as defined in the report by the Technical Committee of the Water Resources Centers of the Thirteen Western States (the Office of Water Resources Research, 1971). A "necessary" condition is described as one in whose absence an effect cannot occur, and a "sufficient" condition (or set of conditions) as one that insures the production of an effect. Thus, the designation of the efficiency criteria as the necessary condition is appropriately justified since in its absence, which would be a case of waste and loss, the overall objective of NED cannot materialize. The other part of the NED objective--"increasing the value of the nations' output of goods and services" may be considered as the sufficient condition (or part of a set of such conditions). Such designation is even more plausible in the framework of balanced growth for here the values of subsectoral outputs and services necessary for the anticipated growth are identified and given in scalar target forms. Meeting these targets insures national economic development, hence (according to the foregoing definition) this aspect is a sufficient condition in the selection of projects. Therefore, to effect NED through project implementation, satisfying the efficiency criteria is a necessary condition without which real NED cannot occur; while meeting the subsectoral target levels of outputs of goods and services, as a sufficient condition, insures the realization of the desired NED.

On the other hand, criteria can take the form of indices and/or constraints. An index is a scoring system for measuring the desirability of an alternative, while a constraint is a limitation on the activity pertaining to an input (cost of project), an output (demand), or a relationship. Thus the necessary condition of economic efficiency may be expressed as an index and made the objective function of the mathematical model.

The Economic Efficiency Criterion to be Used

Due to the fact that outlays and benefits of water resources projects stretch over long spans of time and because of the inherent time value of money (social time preference), the index or measure used to reflect preferability of projects with respect to economic efficiency must be a discounted measure. There are three such measures that are most commonly used at present--the benefit-cost ratio, the net present worth, and internal rate of return. Although each can be determined in several different ways in practice, they can be expressed formally as follows:

$$\text{Benefit-cost ratio} = \frac{B}{C} = \frac{\sum_{t=1}^{T} b_t(1+i)^{-t}}{\sum_{t=1}^{T} c_t(1+i)^{-t}} \qquad (4\text{-}1)$$

$$\text{Net present worth} = S = \sum_{t=1}^{T} (b_t - c_t)\,(1+i)^{-t} \qquad (4\text{-}2)$$

Internal rate of return is that discount rate r such that $S = 0$, i.e.,

$$r = i,\ \text{s.t.}\ \sum_{t=1}^{T} (b_t - c_t)\,(1+i)^{-t} = 0$$

in which

b_t = benefits in each year

c_t = costs (outlays) in each year

i = interest (discount) rate

t = 1, 2,..., T. number of years (T = life of project).

In the absence of financial limitations and when the opportunity cost of capital (or social time preference rate) is used for discounting, use of all the three measures leads to the selection of a unique set of projects since the formal criteria for acceptance of all the three measures (Chapter III) say nothing more than to accept all projects whose benefits offset their costs.[1] Unfortunately, the real world presents a much more complex situation of scarcity, and diverse interest rates are in use simultaneously.

Use of the B/C ratio for ranking purposes may lead to error since it discriminates against projects that have high gross returns and operating costs even though they may possess higher net worth (and hence mean more production and growth) than projects with relatively higher B/C ratios (McKean, 1958). Although the internal rate of return may successfully be used in ranking projects, it is also liable to cause erroneous choice when mutually exclusive or interrelated projects are involved in the choice. Another negative feature of the internal rate of return is that sometimes it is possible to find more than one interest rate that will make the present worth of benefits equal to the present worth of costs. This may happen in cases where costs of relatively high magnitude (comparable to investment) occur later in the project life (e.g., due to replacements of major parts or machinery).

The net present worth (NPW), being an absolute value and not a relative measure, cannot be used for ranking acceptable alternative projects. Yet, it is the most straightforward, discounted cash flow measure of project worth in terms of concept and calculation.

As stated in the previous chapter, when balanced economic growth is being pursued, ranking of projects on the basis of only an efficiency criterion is inappropriate. Also in such a case, a measure that indicates the net worth (value) in absolute terms (rather than in some potentially misleading relative terms) is more relevant, easily comprehensible, and more reflective of the overall NED objective. Furthermore, as

[1] This is assuming that there are no proposals for which more than one internal rate of return (roots) makes S=0.

de Neufville and Stafford (1971) concluded, the net present worth is the single best criterion in situations where the capital resources are limited and must be allocated to the most productive projects, which is the rationale stipulated earlier for the selection of projects. Consequently, the NPW will be the index used to assess the efficiency of projects. The objective function of the mathematical model for the optimal selection of projects for implementation will be to maximize the total net present worth. A case in point is that all the projects that are being considered for implementation are economically feasible. The model is intended to select that mix of projects which, as a program, has maximum economic efficiency while satisfying the demand levels for subsectoral outputs of goods and services deemed necessary for the anticipated economic growth.

In using the net present worth, as is the case for all discounted measures and apparent from Eqs. (4-1) and (4-2), as a criterion for project analysis, the discount rate and the length of the project life are parameters of cardinal importance. Past experiences have shown a drastic change in the number of feasible projects for relatively slight change in the value of these parameters. Studies by Fox and Herfindahl (1964) indicated that out of the number of projects authorized for construction by the Corps of Engineers in 1962 evaluated at an average discount rate of 2-5/8 percent; 9, 64, and 80 percent of them showed negative net present worths when evaluated at 4, 6, and 8 percent, respectively. The subject of what discount rate to use in selecting water resources projects in situations prevalent in developing countries (Chapters II and III) are briefly treated in the following section. For more detail, as well as differing points of view, refer to U. N. (1972); Maass (1962); U. S. Joint Economic Committee (1969); U. S. Water Resources Council (1973).

The Discount Rate and Period of Analysis

The choice of the discount rate and of the life of the project are clearly major determinants of the relative merit of projects. This is especially true and of particular importance with regard to large-scale engineering (infrastructure) projects since it is typical of these works for their relatively high investment costs to come in the very early time period and the relatively small benefit stream to come in the distant future. The discounting procedure is as biased as the human nature that devised it in that it attaches higher preference for present or near future dollars and hence gives them higher weights and less weight and preference for dollars to come in the distant future. This, of course, is incongruent to the acquired instinct of mankind for the aspiration of a brighter tomorrow.

The relative preference and thus greater weight for present and immediate future consumption of the discount procedure, when coupled with high discount rate, favors projects that yield profits in the immediate future (i.e., short-term and small projects) and leads to the exclusion of large-scale projects with long gestation periods, which is characteristic of water resources and infrastructure types of projects that are absolute necessities for meaningful and sustained economic development of any nation. Nevertheless, use of too low discount rates should be guarded against for they will mean inefficient use of resources as scarce as capital resources. Certainly, the difficulty in determining the appropriate discount rate can hardly be underestimated. One possible way of handling it is presented in this section.

The discount rate: The different recommendations for the determination of the appropriate discount rate to be used in the evaluation of public projects (commonly known as the social rate of discount) seem to be rooted primarily in one of three bases, or some combination thereof. They are:

1. Opportunity cost of capital;
2. Time preference of society;
3. Cost of capital.

Recommendations based on (1) suggest that "...the correct discount rate for the evaluation of a government project is the percentage rate of return that the resources utilized would otherwise provide in the private sector" (Baumol, 1969). This statement assumes existence of an economy with perfect competitive market and high level of employment as well as a profit maximization objective as the single criterion for investment decisions. Based on the foregoing assumptions, Baumol observes the discount rate to be the arbiter of the allocation of resources between private and public enterprise. Such observation and recommendation might well be correct and appropriate given the entire scope of assumptions and objectives intact; yet, as elaborated in Chapter II, neither the market conditions nor the objective of the economic activities of most developing countries, if not that of all, are the same as stated above; and therefore the concept may be inapplicable if not inoperative in these countries.

The establishment of a discount rate for public projects that would reflect the time preference of society is inoperative for two reasons. First, it is practically impossible to arrive at a single interest rate that all members of a society would agree to as being the value of their preference to forego consumption at present for one at a specified future time merely because of the simple fact that even a unit of money at present has different real value to different people. This leads to the second reason and what would seem as a natural way to solve the dilemma faced in the first reason; i.e., let the government decide the discount rate based on what it knows or thinks to be the time preference of society. In reality this would mean to leave it to the whims of some civil servant or a group of bureaucrats. This clearly would not reflect the actual time preference of the society.

The most operative procedure which is applicable to conditions prevalent in developing countries is to determent the discount rate based on the cost of capital used for public projects. The cost of capital resource used for investment by the government in the development of water and related resources is not a unique value even for a given year since the government's sources of capital are several. Furthermore, even if matters are simplified by considering the amount of investment of a given project to have come from general public fund, the fact remains that the government acquires its funds at different costs and in different amounts from any number of sources available to it. A typical list of possible sources of capital resources available to most of the developing countries would include government bonds and securities; different types of taxes and tariffs; loans from foreign countries, foreign banks, and local banks; etc. Therefore, the interest rate to be used in project analysis for discounting future costs and benefits, or otherwise converting the same to a common time base, should be based on the weighted average rate of cost of capital available to the government for investment purposes. This, of course, should be the lower bound for the value of the actual rate to be used. A rather simplistic formula for the determination of the social rate of discount may be expressed as follows:

$$i > \frac{1}{N} \sum_{j=1}^{N} i_j \, k_j \qquad (4\text{-}3)$$

in which i = the social rate of discount

i_j = cost of capital from the j-th source

$k_j = \frac{c_j}{C}$ = the weight of the j-th source of capital

c_j = the amount of capital obtained from the j-th source

C = the total amount of capital used for public investment

N = total number of source of public capital resources.

This procedure has both precedence and acceptance. Most developing countries use a social rate of discount for public projects in the range of 8 to 15 percent in line with what the major financing organizations charge as cost of their capital (de Neufville and Stafford, 1971; Gittinger, 1972). In particular, Gittinger states that 12 percent seems to be the most popularly used among developing countries, while the World Bank uses 10 percent in project evaluation.

Projects that involve tied loans and grants should be treated in isolation as special cases in conjunction with their own merits and circumstances. Such treatment will minimize complications of the mathematical modeling problem and simplify the project analysis work.

Period of analysis: Determination of the length of the period of analysis is a more plausible issue than that of the discount rate. The period of analysis should be the lesser of:

1. The physical (technical) life of the project.

2. The economic life of the project.

This is in agreement with the recommendations of the U.S. Water Resources Council (1973). The physical life of a project is the duration of time through which the project is expected to render useful service without substantial decrease in capacity, without the necessity to replace a major investment item, or shut down due to technical obsolescence.

The economic life of a project is the period of time when further discounted values of project benefits and costs have no significant effect on the decision being made--design, selection, etc.

This is evident from the form of the discount factor function:

$$F = (1 + i)^{-t} \qquad (4\text{-}4)$$

and

$$\lim_{t \to \infty} (1 + i)^{-t} = 0 .$$

That is, for a given discount rate, i, the discount factor asymptotically approaches zero as the length of time increases. Furthermore, the convergence to zero is reached faster as the discount rate is increased which could easily be observed from tables of compound interest factors (Grant and Ireson, 1970).

The second criterion is the basis for an almost universal use of a maximum of 50 years as the economic life of water resources and other large scale projects with long physical life.

Component Procedures of the Methodology

A methodology for selection and timing of projects that is to be based on the rationale stipulated at the beginning of this chapter, must incorporate analytical procedures for the following:

1. Simulation of the economy.

2. Assessment of demands for the outputs of each sector of the economy--in this case that of the water resources sector.

3. Assessment of the potential output capabilities of the water resources sector.

4. Optimal selection and timing of projects--selection and timing of projects such that the objective is optimized while the relative constraints are satisfied.

5. Feedback and test of selection.

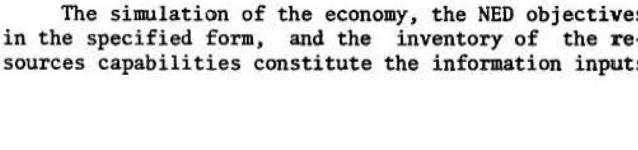
The interconnection of the above mentioned component procedures of the methodology is depicted in Fig. IV-1.

The economy must be simulated to study the structure and interaction among the different sectors as well as aid in making an assessment of the sectoral share of outputs of goods and services towards fulfillment of NED objectives specified by policymakers.

Selection of projects according to the rationale stipulated in the preceding section calls for the assessment of demands on one hand and supply on the other. The NED objectives in conjunction with the economic simulator will be used to project the demands for each type of outputs of goods and services while the possible amount of the supply of such goods and services will be known from engineering studies of project investigation and design.

Once the demand level is established and the potential resources capabilities known, mathematical programming techniques shall be employed to decide which projects to implement in order to satisfy the estimated demands. Such an undertaking requires an iterative approach and hence, feedback and adjustment must be carried out as new information is learned during the entire process.

The entire methodology could be considered as a system composed of the three classical elements of any system: Inputs; white, gray, or black box, as the case may be; and outputs.



The simulation of the economy, the NED objectives in the specified form, and the inventory of the resources capabilities constitute the information inputs.

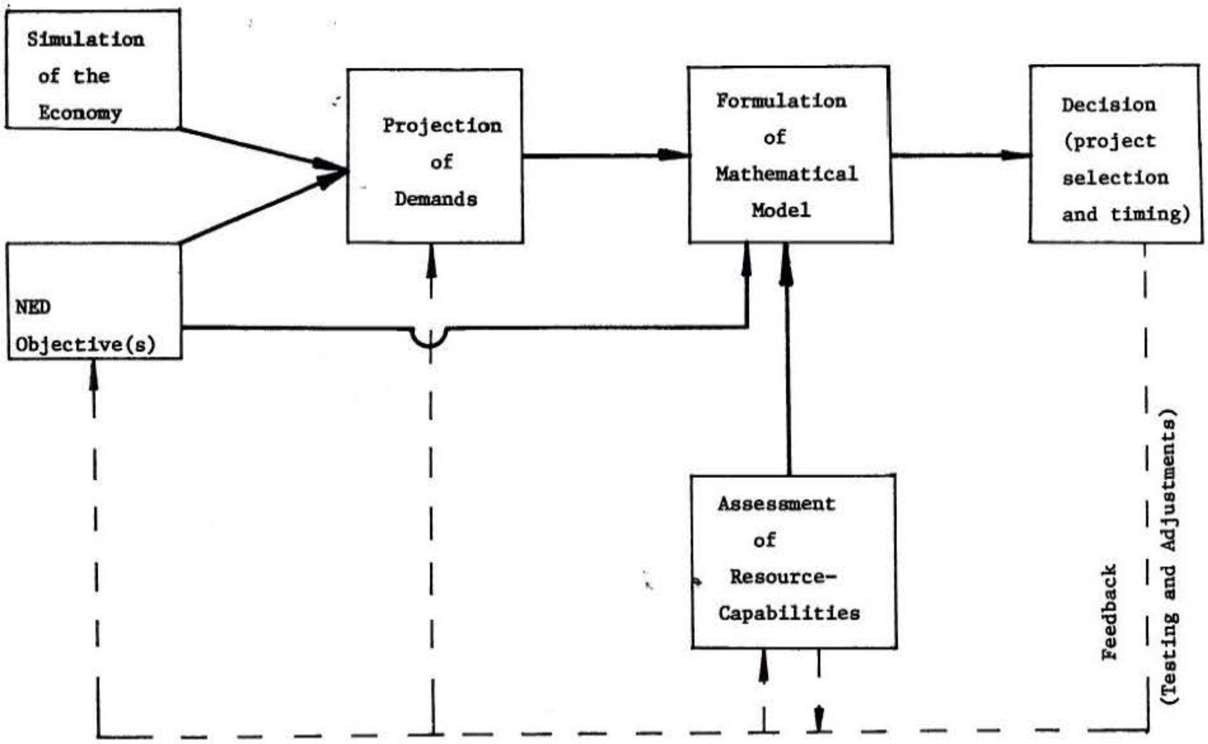


Fig. IV-1. Component Procedures of the Methodology.

The analytical procedures of demand projection and the mathematical modeling and programming constitute what in this case may be called a gray or even a white box. Then, of course, the selected group of projects which make up the water resources development program are the output of the methodology. The testing and adjustments carried out by sensitivity analysis and similar other procedures comprise what in general is referred to as feedback.

Details of the major procedures are presented in the following sections.

Simulation of the Economy

Simulation is a miniature or abstract representation (a model) of a large scale system or phenomenon. The model may be in the form of physical, conceptual, or mathematical terms, or a combination thereof. The purpose of such representation is to facilitate the study and understanding of the real system which would otherwise be too cumbersome and intricate to handle.

In economics, the model is usually a system of equations representing a particular or composite aspect of some real (or assumed) economic phenomena. The concept of a model as a system of equations, representing a simulated reality, is useful for varied purposes such as: a general study of the overall behavior as well as the interactions of the different component parts of the whole system; introduce changes, in the form of projections or otherwise, and study possible adverse and favorable consequences before actually effecting any of the contemplated changes to the prototype. Similarly a model that simulates an economy will aid in studying the economic structure and in conducting structural analysis which is the investigation of implications of interactions of sectors due to changing autonomous parameters.

By making use of such models, planners can explore "inter alia," the implications of given national objectives--e.g. maximization of national products and likely subsequent bottlenecks or excessive surpluses of demands or production (supply)--and thus enhance their rational choice in framing the national long-term investment program as well as avoid potentially undesirable courses of action.

The input-output model will be used in this study as the simulator of the national economy for it is believed to be the best suited analytical procedure available for the aforementioned purposes.

General Description of the Input-Output Model

The input-output table (model) is basically a double-entry accounting system which records the transactions between individual sectors (or subsectors as the case may be). The main function of interindustry accounting is to trace the flow of goods and services from one sector to another. The transactions table (Fig. IV-2), which is the formal format for presentation of the interindustry accounts, depicts the demand and supply relationships of the economy in equilibrium at a given time. It also shows the final demand for goods and services and the interindustry transactions required to satisfy the demand.

The four major quadrants of the table result from the distinctions made between the four different transactions: intermediate and final use of output, and produced and primary inputs.

Quadrant I--The Final Demand (FD) Sector contains the final use of produced goods and services, broken down by major types of uses. It is also known as the autonomous sector since it is here that changes occur which are transmitted throughout the rest of the table.

Inputs / Outputs		Purchasing Sectors: Intermediate Demands — Purchasing sectors 1 .... j .... n	Total Intermediate Demands	Final Demands: Investment	Consumption	Government	Exports	Total Final Demands	Total Supply = Total Demands	Supply: Imports	Gross Total Production	Gross National Product
	1	$X_{11} \cdots X_{1j} \cdots X_{1n}$	W_1	I_1	C_1	G_1	E_1	Y_1	X_1	M_1	D_1	Z_1
	2	.	.									
	.	. (Quadrant II)	.			(Quadrant I)						
Producing sectors	.	.	.									
	i	$X_{i1} \cdots X_{ij} \cdots X_{in}$	W_i	I_i	C_i	G_i	E_i	Y_i	X_i	M_i	D_i	Z_i
	.	.	.									
	.	.	.									
	n	$X_{n1} \cdots X_{nj} \cdots X_{nn}$	W_n	I_n	C_n	G_n	E_n	Y_n	X_n	M_n	D_n	Z_n
Total produced inputs		U_1 U_j U_n										
Payments sector (Primary inputs or Value added)		V_1 V_j V_n (Quadrant III)		V_I	V_C	V_G (Quadrant IV)	V_E		V		V_D	V_Z
Total outlay		X_1 X_j X_n		I	C	G	E	Y	X	M	D	Z

Fig. IV-2. Interindustry Accounting System[2].

Quadrant II--The Processing Sector contains the industries that produce goods and services as well as the interindustry accounts. Each entry X_{ij} represents the value of the output of industry or sector i at the left (producing sectors) sold to industry or sector j along the top of the table (purchasing sectors). The entire set of these entries $\{X_{ij}\}$ make up what is formally known as the transactions matrix. The total intermediate use of a given commodity used for further production is identified by W_i, and the total purchases from other sectors by a given industry or sector as U_j.

Quadrant III--Payments Sector contains the use of inputs which are "primary" in the sense of not being produced within the system. Primary inputs are uses of such primary factors as labor, land and existing capital (in static models). It is often represented in a row vector form as the difference between the value of output and cost of inputs produced outside the system and hence referred to as value added (V_j). When preferable, this sector may be disaggregated into: gross inventory depletion, import, payments to government (taxes, etc.), depreciation allowances, profits, households (wages, salaries, dividends, interests, etc.), and so on.

Quadrant IV--This is a continuation of the Payments Sector and contains the direct input of primary factors to final use (mainly in the form of government employment and domestic services).

The last three columns of Fig. IV-2, added with the express intention of facilitating the use of the input-output model for the present study, break down the total supply of each commodity into imports (M_i), total gross output (D_i) and gross national product (Z_i).

Using the notation adopted in the table, the accounting is done according to the following relationships (Chenery and Clark, 1964):

$$W_i = \sum_{j=1}^{n} X_{ij} \qquad (4\text{-}5)$$

$$U_j = \sum_{i=1}^{n} X_{ij} \qquad (4\text{-}6)$$

$$Y_i = I_i + C_i + G_i + E_i \qquad (4\text{-}7)$$

in which I_i = value of commodity i disbursed for investment. This category of final demand may be further subdivided into gross inventory accumulation, gross private capital formation, etc.

Y_i = final demand for commodity i .

$$X_j = \sum_{i=1}^{n} X_{ij} + V_j = U_j + V_j \qquad (4\text{-}8)$$

[2]The notations and the general format of the Input-Output model (with minor alterations to suit the purpose of this paper) as well as the descriptions of its basics are mainly after Chenery and Clark (1964) and Miernyk (1965).

Equation (4-8) states that the total production in each sector is equal to the value of inputs purchased from other sectors plus value added in that sector:

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i = M_i + D_i = W_i + Y_i . \qquad (4-9)$$

Equation (4-9) states that for each commodity total supply (M_i+D_i) is equal to total demand (W_i+Y_i).

$$\sum_{i=1}^{n} D_i = \sum_{i=1}^{n} (X_i - M_i) \qquad (4-10)$$

-Total Production

$$\sum_{i=1}^{n} Z_i = \sum_{i=1}^{n} (Y_i - M_i) \qquad (4-11)$$

-Gross National Product (GNP)

A case in point here is the distinction to be made between GNP(Z) and total gross supply (TGS)(X) (sometimes referred to as total gross output) or total gross outlay (X) (see Fig. IV-2). Such distinction is important for both conceptual and operational reasons. The GNP, more precisely defined, is "the current market value of final goods and services produced in a given year." It is the indicator of national income and growth, and as such, double counting of values of goods and services produced is strictly avoided in its computation. On the other hand, the input-output table is designed to measure all transactions in the economy. Some goods may enter into more than one transaction, and hence their values counted more than once. Though this may seem to suggest that these are contradicting issues, by properly identifying and setting the input-output table it can be made to serve both purposes. As Miernyk says (1965), input-output analysis and national-income accounting are not two separate branches of economics. The following explanation in symbols is intended to help clarify the difference stated above as well as enable the setting up of the input-output table for both usages (refer to Fig. IV-2 for identification of symbols).

By definition $GNP = C + I + G + E_x - M$ and $X = Y + W$ where $Y = C + I + G + E_x$, therefore

$$GNP = Y - M = X - W - M \qquad (4-12)$$

In other words, GNP (operationally speaking) is the sum of the final demand vectors less imports. Furthermore, Chenery and Clark (1964) show that $GNP = \Sigma V_j$ by deriving that $\sum_j V_j = \sum_i Y_i - \sum_i M_i$ and thus indicating the reconciliation of the input-output and national accounts.

In the OBERS (Office of Business Economic Research Services) procedure of national accounts, GNP is determined as the sum of private and government gross products (U. S. Water Resources Council, 1972) which in turn are determined as products of man-hours worked and average output per man-hour in the respective areas of private and government sectors of employment of the productive work force.

Since there is not a unique way of setting up the input-output table, the advantages to be gained from setting the table in the most conducive form, for the purpose of its intended use, whenever the situation permits, cannot be overemphasized. Figure IV-3 is set up in the form best suited to the purpose of the current study. This was achieved by adding the last three columns and including a water resources sector as mentioned earlier in this chapter.

Important Matrices in Input-Output Analysis

The elements of Quadrant II (the processing sector), excluding the row and column sums, comprise the elements of the transactions matrix:

$$[X] = \begin{bmatrix} X_{11} \cdots X_{1j} \cdots X_{1n} \\ \vdots \quad \vdots \quad \vdots \\ X_{i1} \cdots X_{ij} \cdots X_{in} \\ \vdots \quad \vdots \quad \vdots \\ X_{n1} \cdots X_{nj} \cdots X_{nn} \end{bmatrix}$$

necessary for the calculation of a second matrix, critical to the input-output solution, the matrix of direct or technical coefficients.

The "technical coefficients matrix" is obtained by dividing each entry X_{ij} by the total outlay of the corresponding sector X_j ;

$$A = [a_{ij}] = \left[\frac{X_{ij}}{X_j}\right] = \begin{bmatrix} a_{11} \cdots a_{1j} \cdots a_{1n} \\ \vdots \quad \vdots \quad \vdots \\ a_{i1} \cdots a_{ij} \cdots a_{in} \\ \vdots \quad \vdots \quad \vdots \\ a_{n1} \cdots a_{nj} \cdots a_{nn} \end{bmatrix} .$$

The elements of the matrix of technical coefficients (a_{ij}), known as direct input coefficients, indicate the amount of inputs (in terms of value) required from each industry (i) to produce one dollar's worth of the output of a given industry (j). This interpretation becomes apparent from how the elements are derived.[3]

$$a_{ij} = \left[\frac{X_{ij}}{X_j}\right] \qquad (4-13)$$

The matrix of technical coefficients is useful in that it enables one to calculate the amount of direct purchases required from each producing industry as a result of an increase (or decrease) in the output of one or more of the industries listed at the top of the table. An even more useful matrix is the one known as the "Leontief inverse" for it shows the total requirements, direct and indirect, of output from all industries per dollar of delivery outside the processing sector, i.e., to final demand sector.

[3]In actual practice, it is the adjusted gross output, which is obtained by subtracting inventory depletion during the period covered by the table from the total gross output (X_j), that is used in determining the direct input coefficients (a_{ij}).

The "Leontief inverse" may be derived from the input-output table as follows. Gross output minus intermediate use equals the new output of the system or final demand, i.e.,

$$X - W = Y$$

or

$$X - AX = Y .$$

Factoring the left-hand side,

$$(I - A) X = Y .$$

To solve for X (in economics terms this problem reads: determine the gross output necessary for a given amount of final demand) the Leontief matrix,

$$L = (I - A) = [\ell_{ij}]$$

must be an invertible (nonsingular) square matrix, i.e., it must have a nonzero determinant--$\Delta = |L| \neq 0$.

$$X = L^{-1} Y = (I-A)^{-1} Y = \begin{bmatrix} 1-a_{11} \cdots & -a_{1j} \cdots & -a_{1n} \\ \vdots & \vdots & \vdots \\ -a_{i1} \cdots & 1-a_{ij} \cdots & -a_{in} \\ \vdots & \vdots & \vdots \\ -a_{n1} \cdots & -a_{nj} \cdots & 1-a_{nn} \end{bmatrix}^{-1} \begin{bmatrix} Y_1 \\ \vdots \\ Y_i \\ \vdots \\ Y_n \end{bmatrix} \quad (4\text{-}14)$$

The expression $(I-A)^{-1}$ is known as the "Leontief inverse" and gives the direct and indirect requirements of each industry per dollar of output to final demand.

The total indirect requirement of each industry can be determined as the following:

$$R = [r_{ij}] = [\ell_{ij}]^{-1} - [a_{ij}] = (I-A)^{-1} - A \quad (4\text{-}15)$$

Application of Input-Output Analysis

Although the inception of the interindustry analysis can be traced back to Quesnay's "Tableau Economique" published in 1758 (Chenery and Clark, 1964), it is only after 1936 when Leontief published the results of his five years of research on an empirical model of the American economy (Leontief, 1936) that the input-output model started to find applications. The following is a partial list of the major applications of input-output analysis:

1. Structural analysis--The use of the model for the study of the properties of an economy, i.e., the study of the structure and the interaction among the parameters of the economy. Tracing the effect of changing the values of final demand parameters (autonomous variables) is an example of structural analysis.

2. Impact or multiplier analysis--This application aids in determining the relative magnitude of changes on key policy indicators (income, employment, output, etc.) as a result of a unit change in investment. Similarly, it may be used to study the relative amounts of income, investment, export, etc. (components of final demand) generated by different sectors of the economy with the apparent help to policymakers and planners in deciding where to intensify investment and where to relax it in order to implement a desired development strategy.

3. Overall economic projection--This particular application of the input-output model enables consideration of developments in all parts of the economy. "Such projection is concerned with analyzing the repercussions of major government policies or programs, such as investment in public works and basic industries for economic development" says Chenery (1964), who also calls this type of projection a "guide to sensible government policies." It is this unique property of enabling consideration of developments in all parts of the economy that is the primary reason for the selection of the technique of projection by means of input-output analysis, over any other projection procedure. to be included as the major analytical tool of the projection procedure of the methodology for the selection and timing of water resources projects. This makes a second major usage of the input-output model by the methodology, the first one being the use of it to simulate the economy based on its capability to describe the structural interdependence of an economy.

Assessment of Demands

Various factors must be considered and several elements taken into account when assessing total demands for outputs of goods and services at some future point in time. The total demand for the outputs of a sector (e.g., water resource sector) consists of intermediate and final demands. On the other hand, the final demands at some future point in time must be consistent with the growth level specified by policymakers in the NED plan for the given plan period. Furthermore, the development strategy chosen by the policymakers must be reflected in the projected levels and mix of the demands.

Steps and procedures to fulfill the assessment of sectoral and final demands for outputs of goods and services necessary to achieve an a priori specified quantitative NED objective and complaisant to a prespecified long range development strategy are presented in this section.

There are four component parts to the assessment process.

1. The NED objective.
2. The development strategy.
3. The final demands.
4. The intermediate demands.

The first two parts are given to planners by policymakers. The NED objective is customarily given as annual rates of increases to GNP. Strategies are stipulated in a score of different manners and more often than not are absolutely indefinite and not amenable to rigorous analysis (see Chapter II).

The elements of final demands are the autonomous or independent variables of the input-output table and as such the ones that are readily accessible for making changes in studying effects of government policies and programs. Thus actual economic projection is made here. Although it is commonly considered that the desired future values of the elements of final demands are to be given to planners and analysts (Chenery and Clark, 1964), and as such they are not to be concerned about the causes of changes in final demands, the autonomous nature of the elements of final demands could advantageously be used to link the NED objective as well as incorporate the preferred strategy of development elected by the policymakers with production. Some possible ways of making such a link are discussed subsequently in this section.

The intermediate demands are the direct and indirect demands by the processing sectors necessary to produce both final and intermediate goods and services. These are dependent endogenous variables. They are dependent on the technology and the level of total final demands.

The assessment of total demands for goods and services of the economy of a country is best done by input-output projection. The primary reason for preferring input-output projection over other procedures is that it is a consistent projection, i.e., when an input-output table is projected, the output of each industry is consistent with the demands for its products (Miernyk, 1965). The importance of this feature in the planning and pursuit of balanced economic growth, which is the reality of most developing countries (Chapter II), cannot be overemphasized.

The assessment of total demands that deploy input-output projection is carried out in three major steps:

1. Projection of final demands.
2. Computation of intermediate demands.
3. Computation of total production requirements.

Projection of Final Demands (FD)

This is done by projecting each element in the final demands sector of the input-output table. The sum of the rows of the projected elements form the new final demands vector. Any one or a combination of a number of approaches may be deployed in making the projection of individual or groups of the components of the final demands. Some of them are briefly presented in the following paragraphs.

Empirical relationships: The different components of the FD are estimated as a continuation of past trends by either some form of extrapolation or fitting some mathematical function. This approach is readily applicable to elements that are regressible with respect to some demographic variables--the elements of the household consumption column are perfect examples. Another example is the Moore-Peterson employment multiplier estimation procedure which uses an employment-production function that measures the relationship between total employment (in man-years) in each industry and the gross output of the industry expressed in millions of dollars (Miernyk, 1965).

Empirical relationships of diverse nature are used, where available, in projecting the entries of the FD sector. Although their usefulness in facilitating such projections is undisputed, their use is limited since there are very few, if any, established relationships for use in even the most cursory type of projection. This is largely because of the fact that such relationships lack universality, and have to be developed (and be constantly updated) on a case by case basis for each country, and the prohibitive nature of data acquisition involved.

Disaggregation of GNP: In this method, the new level of GNP is disaggregated into sectoral components and then dispersed horizontally backwards into the elements of FD according to historical patterns of distribution or some other basis. This approach assumes continuation of past trends and no change in the structure of the industrial system and their share in production. Such an approach may be more appropriate for use in mature economies than for developing ones.

Disaggregation of GNP into sectoral component parts based on strategic reasons such as desired composition of diversification and designating the elements of the FD to ramify the chosen strategy, an approach employed by several countries, is much more suitable to underdeveloped countries than one based on past pattern.

The scarce-factor approach: Priority is given to sectors and industries that either economize scarce factors (mainly capital) or use large amounts of abundant ones (labor intensive). Activities in such sectors are intensified and corresponding elements of the FD increased while those of capital intensive sectors are deferred. The apparent difficulty of delineating the sectors into the foregoing categories hinders the widespread usage of this approach. Multiplier analysis in conjunction with informed judgment can be used to assist in such identification. For example, large entries in the household row of the matrix of technical coefficients of a closed input-output table with respect to the household's sector indicates that the purchasing sector at the top is a labor intensive one.

Key sectors approach: Sectors that are key to the economic development are identified and the corresponding entries in FD are projected according to some guidelines. This is the approach mostly followed by strategists and planners who are proponents of the school of thought that investment in social and public overhead and basic (heavy) industries is the prime mover and an absolute necessity for accelerated and sustained economic development. The usual procedure followed in this approach is one of analogy. A country with an economy of the desired structure and level is selected and the major components of its FD are adopted with some adjustments. This method is very popular among the developing countries because of its simplicity in application and coherence of the approach to the planning on long range bases adopted by these countries.

None of the foregoing approaches can be uniformly applied to arrive at the projected values of each and all entries of the FD sector. Rather, they can be used in combinations or one at a time, depending on the suitability of the approach to the nature of the particular entry and column under consideration, to identify the sectors and columns of the FD that are instrumental to effect the elected strategy. After such sectors and columns are identified the exact level to which an entry of the FD should be projected can be determined by an iterative process that seeks the convergence of the difference between the final demands and imports vectors to the projected (target) GNP level where the latter is the control.

This is the most viable approach that can be recommended at the present time to link the overall NED objective, development strategy, and production of goods and services. It will enable the assessment of total production of goods and services necessary to meet the NED objective targets via an elected development strategy.

A point that needs mention here is that an experienced economist should be consulted in identifying key sectors for the given strategy. The expertise of an experienced economist in this area should be sought and the need for it cannot be overemphasized. Although there is no dispute as to the importance and necessity of such expertise all along the selection and timing of projects for NED, it is acutely indispensable in the phase of identifying key sectors relative to specific development strategies.

Computation of Intermediate Demands (Projection of the Processing Sector)

This computation is carried out to find the transactions by the processing sectors necessary to sustain the newly projected level of final demands. A well established procedure exists to perform such a computation and its steps are given below (Miernyk, 1965).

1. Obtain the projected final demands vector as the row sums of the projected component elements of the final demands sector including projected imports.

2. Compute adjusted projected final demand by first multiplying the projected final demand by the ratio of inventory depletion to final demand in the base year, and then subtracting this amount from the projected final demand.

3. Post multiply the transpose of the Leontief inverse matrix, $[L]^{-1}$, by the adjusted projected final demands vector. The product is the new adjusted total gross output for each industry.

4. Multiply each element in the i-th column of the technical coefficient matrix by the i-th element of the transposed adjusted total gross outputs vector obtained in step 3. The result is the processing sector of the projected transactions table. The row sums of this matrix form the elements of the new intermediate demands vector.

5. To obtain the total gross output vector, add the appropriate inventory adjustment which was subtracted in step 2 to the adjusted total gross outputs found in step 3.[4]

6. Set up the new projected transactions table by entering the computed values of its components in the foregoing steps in their appropriate slots of the tabulation.

Total Production Requirement

The total production requirement is the amount of goods and services that the producing sector has to deliver to both final and intermediate users. The new total production requirement is the sum of the projected intermediate and final demands less projected imports.

Recapitulation

In this section of the paper, a procedure that uses input-output projection in conjunction with the overall NED objective and development strategy to forecast the economic transactions and predict the total production requirements for the outputs of goods and services of the individual sector (and subsector) of the economy has been presented. It is preferable to do the projection in constant prices for the kind of planning and level of decision making that the methodology suggested is addressed to.

The major steps of the projection procedure are as follows:

1. Obtain the overall NED objective in an appropriate form for the planning period(s) under consideration.

2. Obtain the elected strategy for the economic development for the planning period(s).

3. Identify key sectors and elements of final demands that are instrumental in implementing the elected strategy.

4. Project the identified elements of the final demands sector consistent with the policy objective and strategy as per 1 and 2 along with all other final demands necessary for continued growth.

5. Compute transactions of the processing sector and intermediate demands consistent with the projected level of final demands.

6. Compute the total production required from the producing sectors to satisfy the new demand levels for both the final and intermediate uses.

The foregoing projection procedure helps determine the total production of outputs of goods and services necessary to achieve a desired growth level a priori specified by policymakers. The deployment of the input-output projection procedure endows significant advantage in that it enables determination of both direct and indirect requirements to sustain a given level of final demands. The ability to determine all required demands is in turn very important for it will improve the certainty of meeting demands by selected projects and programs and hence attain the aspired level of growth. More importantly, it provides production targets, and near realistic ones, for project selection and program formulation on the aptness of which the warrantee to the aspired growth lies. The selection of projects to meet such targets is to be accomplished through the use of mathematical programming techniques which is presented in the section after the following.

In the next section, assessment of resource capabilities, an apparent prerequisite to project selection and plan formulation, is presented.

Assessment of Resource Capabilities

In order to formulate a program that will meet the projected future demand levels, it is necessary to know the resources capabilities that can readily be employed to satisfy the estimated production requirements. After all, the core issue of the subject of project selection is one of satisfying demand by literally matching supply to demand. Of course it is the output capability of the projects that constitute the available supply.

Assessment of resources capabilities in the area of water resources development involves an extensive and relatively detailed inventory of the quantity and characteristics of water and related resources, appraisal of opportunities for their beneficial use, determination of ways and means of their management and

[4]The appropriate "inventory adjustment" refers to the application of the inventory adjustment referred to in step 2 to the Leontief inverse matrix so that both the direct and indirect effects of the adjustment are accommodated in the new total gross output vector.

exploitation, as well as identification of possible limitations to their full utilization and ways of mitigating such limitations.

The scope and procedures of the investigations necessary for water resources development project-designs and plan-formulations are presented in sufficient detail in publications of the U.N. (1964) and the U.S. Bureau of Reclamation (1972). Thus, presentation of the same here is omitted.

The data necessary in the selection of water resources projects include estimates of: net economic values of project outputs of goods and services; costs of construction, operation, maintenance and replacements; length of project construction period; project life; capital and other resources available for project implementation, etc. The quality of these data must be of high reliability in order to assure the ability of the development program to produce at least the values estimated and that it will be implemented at no more than the estimated costs. Data of such quality are produced as a result of studies conducted at the project-feasibility-study levels.

From the foregoing paragraph, it is evident that assessment of resources capabilities up to and including project-feasibility-studies is a forerunner undertaking to project selection for implementation. Furthermore, project selection involves two or more projects. It is logical that the larger the number of projects to select from the greater the possibility of selecting a set with higher performance (whatever the measure of performance may be). It is also a known fact that such project investigations are expensive ventures and require long ranges of time. It seems one is faced with a dilemma.

In actuality, the cost of investigation is negligible compared to investment costs in water resources development. Therefore, despite the seeming dilemma, water resources project investigation and project formulation up to the economic feasibility level should be carried out on a continuous basis, especially in countries where long range development planning is adopted. In this way, the inefficient (and expensive in the long run) piecemeal approach of solving problems by seeking solutions after problems of critical nature have risen can be avoided. The situation in the countries of the Sahel region of North Africa involving problems caused by drought in 1973-74 should be more than enough evidence to serve as a lesson and grounds for the justification of continuous resources capabilities assessments.

The appropriate format for the presentation of the data for use in the selection and timing of water resources projects should be similar to that used for the example problem (Chapter V).

Optimal Selection and Timing[5]

"Optimal selection" in this study refers to selection of a set of projects that optimize a given objective function, while satisfying all pertinent constraints in the areas of available resources, project relationships, etc. Another dimension of optimality is the timely provision of the water resources project outputs for use by the other sectors of the economy. Specific ways to handle the aforementioned aspects are presented in the present section.

Timing

As stipulated earlier, water resources projects should be timed such that project outputs are available for use by other sectors over the ensuing planning period. This is necessary since most outputs of water resources projects are intermediate goods and as such required by other sectors in the production of their respective outputs.

In light of the foregoing condition for project timing, there may be an inherent problem in cases where a selected set of projects contains one or more projects with necessary construction period longer than the time available between the time its output is scheduled to be made available for use and the time the selection is made. Such possible contradictions could be eliminated by one of two ways.

One way is to check and make the necessary adjustment as a separate exercise after the selection in the feedback and adjustment phase (Fig. IV-1) of the entire process.

The second, and more expedient way, is to include an expression in the body of the mathematical model that would exclude the projects with construction periods in excess of that available.

System Decomposition

Since project selection and formulation of development programs covering the entire economy of any country is a rather large problem, it would be expeditious and advantageous in more ways than one to decompose the problem and tackle it in parts.

The water resources sector, as with most other sectors, is a small enough part compared to the entire economic system, and yet complete and diverse within itself, to be treated as a relatively separate and complete subsystem. Geoffrion (1972) calls such subdivision of large problems into subproblems a "solution strategy," in contrast to "problem manipulations," which are ways of simplification mainly by restatement of the dual of a linear programming problem.

The additive nature of the input-output model, used to simulate the whole economy, is a positive feature in this regard since the concept of "the whole being the sum of its component parts," which is one of the rationale basis of decomposition and resynthesis of large systems, is built into the input-output model.

However, the stage at which a large system is decomposed and the subsystems treated separately is important and may lead to erroneous decisions if done at a stage different from the appropriate one. In the methodology given herein, decomposition is effected only after the total production requirements have been assessed. This is crucial because the production target should include all final and intermediate, direct and indirect demands, lest there be bottlenecks resulting from unsatisfied demands.

Once the production requirements are computed (given in the immediately preceding section), the problem of the selection and timing of projects to meet these requirements can be carried out on a sector by sector basis. Such decomposition decreases the size

[5]For notations used in this section refer to p. iv.

of the problem and makes it manageable, while not affecting the outcome in any way. This is because the projects and programs to be selected to meet the sectoral targets are unique to the individual sectors (see basis for sector identification, U.S. Bureau of the Budget, 1967) and meeting the said demands is the only link that connects (in addition to receiving its own needs of inputs) a given sector as a producing unit to the other parts of the economy.

Therefore, the water resources sector will be treated separately in the problem of the selection and timing of projects needed to meet production targets computed in the manner described in the preceding section. Though a subsystem of the economy, the water resources sector is disaggregated into, as described earlier, subsectors according to types of outputs. Thus the target level of production is expressed as a vector. This target level is determined for each subsector according to the following relationship and schematically displayed in Fig. IV-3.

$$\delta^{\nu}_{\ell\tau} = \delta_{\ell\tau} + 1/2\delta_{\ell,(\tau+1)} + \sum_{v} b_{\ell v} \qquad (4\text{-}15)$$

in which

$$\delta_{\ell\tau} = D_{\ell\tau} - D_{\ell(\tau-1)}$$

$$D_{\tau} = GNP_{\tau} + W_{\tau}$$

$$GNP_{\tau} = \sum_{t=1}^{\rho} GNP_{\tau_o} (1+g)^{t} \qquad (4\text{-}16)$$

or $\qquad = Y_{\tau} - M_{\tau}$

The production target level of a given commodity ($\delta^{\nu}_{\ell\tau}$), which the new projects to be selected are to provide, is determined as the sum of the difference between the total output requirement level at the beginning of a given future planning period ($D_{\ell\tau}$) and the one prior ($D_{\ell,(\tau-1)}$), plus half of what is required for the next planning period ($\delta_{\ell,(\tau+1)}$) and the amount of capacity lost due to termination of the services of existing projects ($\sum_{v} b_{\ell v}$). All these parameters are to be expressed in terms of their market values.

A production level determined in the foregoing manner provides for the average requirement over the length of each successive planning period. Such provision, coupled with interim revisions and updating of the selected projects and programs within the longer ranges, as more information becomes available, should enhance both flexibility and adequacy of the water resources program.

Mathematical Programming Technique

The general mathematical programming problem is to solve a mathematical problem (presented as a mathematical model), i.e., it is to find the optimum value (maximum or minimum, as the case may be) of an objective function while satisfying all the constraints. In Plane's (1971) words: "Mathematical programming is the family of mathematical manipulation techniques which solves the general mathematical programming problem." Mathematical programming techniques are as different and diverse as the mathematical problems (models) they seek to solve, which in turn are as diverse as the real world problems which the mathematical models seek to depict.

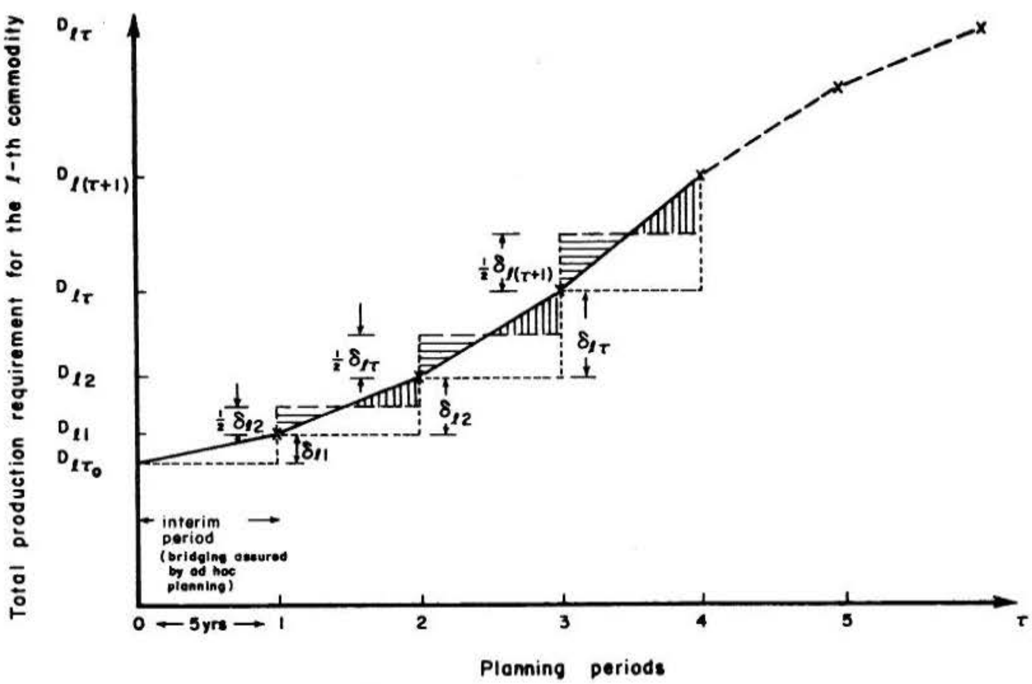


Fig. IV-3. Graphic Representation of Demand in Time.

The selection of the programming technique depends upon several factors such as: nature of the real world problem to be programmed, the form of the objective and constraint functions, the form of the available data, available or known technique to the programmer, and other similar aspects.

The programming technique employed for tackling the selection and timing of water resources projects is the zero-one integer linear programming technique. Zero-one integer linear programming is the best suited technique for the problem that this study is addressed to for the following reasons:

1. The objective and constraint functions are linear.

2. The selection of a set of projects is a process characterized by a combinatorial phenomenon.

3. The indivisibility of the water resource projects (i.e., in the selection of projects for implementation, a project is selected as a whole unit or rejected). In other words, it is meaningless to have fractions of projects as the solutions to the mathematical model.

4. It has comparatively less dimensionality problem when considering multipurpose, multiproject, and multiple time frame. This would be a problem in particular, if dynamic programming were to be used (Butcher, Haimes, and Hall, 1969).

5. The relatively readily availability of computer codes.

The strength and scope of application of zero-one integer linear programming are given extensive coverage in the literature in the works of Balinski (1965), Pritsker et al. (1968 [b], [c]), Watters (1968), Plane and McMillan (1971), and others.

In zero-one integer programming, the decision variable takes either of the binary values of 0 and 1. Thus in the present study

$$P_{k\tau} = \begin{cases} 1 & \text{if project number } k \text{ is selected for implementation by the beginning of plan period } \tau \\ 0 & \text{otherwise.} \end{cases}$$

Mathematical Model

The main aspects of mathematical modeling are the identification of the relevant variables (parameter identification) and formulation of the functional relationships of the variables required to model the situation under study. Thus, a mathematical model is a representation of the relationships of the pertinent parameters of a real world problem in the form of an objective function and constraints. The logical basis and the steps of constructing mathematical models are elaborated at length by Pritsker et al. (1968 [a]) and will not be repeated here.

The overall objective of this paper is to develop a methodology for the optimal selection of water resources projects that will enhance economic development. In the foregoing sections, procedures for making projections of outputs of goods and services consistent with NED objectives have been presented. Furthermore, what is to constitute the objective and constraint functions have been delineated and stipulated; in explicit terms and in full for the former and in part for the latter. Here, the mathematical model for the optimal selection of water resources projects will be presented in a more complete form.

The specific problem to be translated into a matehmatical model is:

> Select a set of water resources projects {p}, for implementation by the planning period number τ , out of a given set of economically feasible projects K , that maximize economic efficiency (as measured by net present worth of projects) while satisfying the production requirement levels and without exceeding a given budgetary limitation, as well as other constraints pertinent to the situation.

The Principal Mathematical Model

$$\underset{P_{k\tau}}{\text{Maximize}} \sum_{\tau=1}^{N} \sum_{k=1}^{K} S_{k\tau} P_{k\tau} \qquad (4\text{-}16a)$$

Subject to:

1. Satisfaction of production targets

$$\sum_{k=1}^{K} \bar{b}_{\ell k\tau} P_{k\tau} \geq \delta^{\nu}_{\ell\tau} \text{ for } \begin{array}{l} \tau = 1, 2, \ldots, N \\ \ell = 1, 2, \ldots, n \end{array} \qquad (4\text{-}17)$$

2. Budgetary constraints

$$\sum_{k=1}^{K} C_{k\tau} P_{k\tau} \leq \bar{C}_{\tau} \qquad \tau = 1, 2, \ldots, N \qquad (4\text{-}18)$$

3. Bivalency (zero-one) constraint

$$P_{k\tau} = 0 \text{ or } 1 \qquad (4\text{-}19)$$

4. Nonexceedence of length of available time by project construction time (or project maturity time)

$$\theta_k P_k \leq \rho\tau \qquad (4\text{-}20)$$

Observance of the above stated condition can be brought about in several other ways such as the following:

a. forced exclusion of projects until the necessary construction and maturity time has elapsed. This concept is in effect the converse of consideration 9 stated further below. The expression to be used is the following:

$$\sum_{j\varepsilon J} P_{j\tau} = 0 \qquad (4\text{-}21)$$

in which J is the set of projects being excluded;

b. another way would be to create dummy projects, with zero costs and benefits, and require their implementation at such time when the length of construction and maturity time of their real counterparts has elapsed while making the real projects contingent upon the corresponding dummy ones (see considerations 7 and 9 below).

5. Non repetitive selection of any given project

$$\sum_{\tau=1}^{T} P_{k\tau} \leq 1 \qquad (4\text{-}22)$$

$S_{k\tau}$ and $C_{k\tau}$ in (4-16a) and (4-18), respectively, are defined as follows:

$$S_{k\tau} = \sum_{t=1}^{\tau} S_{k\tau_o} (1+i)^t \qquad (4\text{-}23)$$

$$S_{k\tau_o} = B_{k\tau_o} - C_{k\tau_o} = \sum_{t=0}^{T} s_{kt}(1+i)^{-t} =$$

$$= \sum_{t=0}^{T} \sum_{\ell=1}^{n} b_{\ell kt}(1+i)^{-t} - \sum_{t=0}^{T} c_{kt}(1+i)^{-t} \qquad (4\text{-}24)$$

$$C_{k\tau} = \sum_{t=1}^{T} C_{k\tau_o}(1+i)^{-t} \qquad (4\text{-}25)$$

$$C_{k\tau_o} = \sum_{t=0}^{T} c_{kt}(1+i)^{-t} \qquad (4\text{-}26)$$

Note: Since it has been suggested that the projection of the input-output model, and hence, that of the total production level, be done in constant prices, the value of average project outputs, $b_{\ell kt}$ and not discounted value of benefits should be used in (4-17) at subsequent plan period (τ = 1, 2,...,N).

Additional Considerations

In addition to the constraints stated as part of the principal model, appropriate expressions that will take into account pertinent relationships particular to the situation at hand must be included in order to ensure a sound decision. These are mainly cases of project relationships and matters such as ensuring inclusion of an isolated project deemed necessary for reasons other than those incorporated in the mathematical model. Mathematical expressions for incorporating some of the cases that may frequently be encountered in the selection and timing of water resources projects are given below as continuation of the body of constraints of the entire mathematical model.

6. Mutually exclusive projects--These are a set of projects {L} out of which only one can be selected, i.e., acceptance of one project precludes acceptance of all others in the set. Such projects are encountered in water resources when there are two or more alternate project designs for a given site or in the case when there are a number of impoundment projects on sites located at very close range to each other that only one site could be used. One equation of the following type should be added for each set {L} of mutually exclusive projects.

$$\sum_{k\epsilon L} \sum_{\tau=1}^{T} P_{k\tau} \leq 1 \qquad (4\text{-}27)$$

7. Contingent projects--When acceptance of a project (k) is dependent on the acceptance of another project(s) (j), thus making the first project contingent on the acceptance of the latter. This is also a rather frequent reality among water resources projects. The following type of relationship should be added for each pair of contingent projects.

$$P_{k\tau} - \sum_{t=1}^{\tau} P_{jt} \leq 0 \text{ , } \tau = 1, 2, \ldots, N \qquad (4\text{-}28)$$

8. Compulsory precedence--When the acceptance of a project (k) may be possible only after the passage of a given number of periods of time (α) after the acceptance of project (j). Such a condition can be imposed by the following relationship.

$$P_{k\tau} - \sum_{t=1}^{\tau-\alpha} P_{jt} \leq 0 \text{ , } \tau = 1, 2, \ldots, N \qquad (4\text{-}29)$$

9. Compulsory acceptance--This is a situation when implementation of a project (k) is deemed necessary for reasons other than incorporated in the mathematical model. To insure inclusion of such a project in the selected set of projects, the following expression should be added for each such project.

$$\sum_{\tau=1}^{N} P_{k\tau} = 1 \qquad (4\text{-}30)$$

Compulsory deferment is expressed by making the right-hand side equal to zero.

A special case would be when the implementation of project k is desired to take place at time $\tau = \gamma$. In this case expression (4-30) takes the following form.

$$P_{k\gamma} = 1 \qquad (4\text{-}31)$$

Independent projects, those projects whose acceptance is not affected by the inclusion of others, do not require special treatments. The principal model is adequate for their selection. Another case that needs to be mentioned here, although its treatment is almost apparent, is the case when a project can be implemented in stages. This case may be handled by considering each possible successive stage as a separate project and by including in the model the appropriate contingency compulsory precedence and mutually exclusivity constraints. For example, a project that can be implemented in (n) stages may be represented as (n + 1) separate alternative proposals and the set can be included in the mathematical model by making appropriate use of expressions given under 6, 7, and 8.

An Alternative Problem

The foregoing mathematical model is formulated for a situation where the budgetary ceilings are a priori specified.

More often, in the real world, officials responsible for the development of the water and related resources of a country are charged not only with the task of formulating and carrying out programs consistent with the NED objectives stipulated in the periodic national development plans, but must also submit requests for appropriation of funds necessary to implement the programs.

In such cases the problem may be formulated as follows:

Which are the projects to be included in the water resources program as part of the overall action program of the long range national development plan and what is the least amount of investment necessary to be appropriated from the national treasury?

The mathematical model for this problem is the following:

$$\text{Minimize} \sum_{\tau} \sum_{k} C_{k\tau} P_{k\tau} \tag{4-32}$$

subject to all the constraints of the other model except the budgetary constraint.

Feedback: Testing, Analysis, and Adjustment

This section is included to stress the need of learning by gathering new information as well as by conducting tests on the decisions arrived at and making the necessary adjustment in order to achieve better end results. Such activities include "inter alia" infeasibility analysis, sensitivity analysis, and so on.

Infeasibility

Infeasibility of solution to the mathematical programming problem may be caused, among other reasons, due to infeasibility of the development program.

The primary reasons for infeasibility caused by the development program are by and large related to inadequacy in resources necessary to carry out the desired level of growth. Specifically, this may be either insufficient capital resource to fund all projects necessary to meet the production target or lack of water resource sector capabilities in the sense that the outputs of the known projects are short of meeting the target demand levels.

On the other hand, the NED policy adopted might have been unrealistically ambitious and was made without consideration of the nation's resources base.

By relaxing each type of constraint, one at a time, the decision maker (or the analyst) may learn the bottleneck area and, using additional information and informed judgment, recommend measures to alleviate the bottleneck, thereby hopefully converging to a feasible solution. Some possible steps that may be recommended to alleviate the aforementioned causes of program infeasibilities are:

1. Seek and secure additional capital resources. This is in the case when the violation of the capital resource constraint is responsible for the solution infeasibility.
2. Lower the level of the NED objective to some acceptable level without jeopardizing the long-range growth.
3. Initiate a crash program of identification and study of potential water resources projects.
4. Seek administrative policy measures that may be used to alleviate the bottleneck.

Furthermore, other measures based on informed judgment by interdisciplinary groups should be sought and the model as well as the decision subsequently updated and readjusted. It should be well remembered that the selection process, as any other major part of development planning, is an iterative process and the mathematical model can only help the process by enabling easier detection of bottlenecks and expediting the analysis of alternative policy trials. Of course, as a better information base develops the number of such iterations should decrease.

Sensitivity Analysis

Sensitivity analysis is a technique used to analyze the sensitivity of the optimal solution to changes or uncertainty in the input data. There are several questions to which sensitivity analysis may be employed to gain insights. Certainly it is also an invaluable means of improving the quality of diverse kinds of decisions. The many techniques and uses of sensitivity analysis are adequately presented by Dantzig (1963), Wilde and Beightler (1967), de Neufville and Stafford (1971), and in almost all books in the field of Operations Research (e.g., Hiller and Lieberman, 1969).

As the parameters used in the selection model (water resources capabilities, capital and other related resource availabilities, as well as the production requirement levels) are seldom known with a reliable degree of accuracy, as they are only estimates, the planner or the analyst must couple the optimal project selection with an investigation of the sensitivity of the optimum selection to possible changes in these parameters. Such sensitivity analysis is an inevitable feature of project selection exercises, especially in light of the possible repercussions and consequences inherent in an overall program being formulated to effect balanced and coordinated economic development.

The most important types of sensitivity analysis to be conducted when carrying out optimal project selection using a zero-one integer linear programming technique are those concerned with variation of the constraint vector--mainly the elements of the target levels in the case of the present study. This type of sensitivity analysis is known in the literature as "specification sensitivity analysis" (de Neufville and Stafford, 1971). Analysis of the effect on the optimal solution of perturbations in the elements of the constraint vectors would help determine the sensitivity of the selection to inaccuracies in the projection of demand levels. It may also aid in detecting bottlenecks mentioned in the foregoing section and hinting ways of alleviating them.

Chapter V
ILLUSTRATIVE EXAMPLE

In this chapter an example problem based on hypothetical data is set up to illustrate the application and to demonstrate the workability of the methodology developed in Chapter IV.

Due to the unavailability of the necessary data in the appropriate form, application of the methodology could not be demonstrated on an actual case of a given country. However, separate parts of the data used in the example problem represent actual cases since they have been taken from documents of several countries. Thus, while the example problem is not concerning a particular country, it is conceivable that there could have been a country with the given economy, NED objectives and strategies, as well as the resources used in this example problem. Besides, the purpose to be served here is not so much to conduct a case study as it is to illustrate the mechanics of the application of the methodology. It is also hoped that using semi-hypothetical data (as opposed to one using entirely hypothetical data) will make it evident that the necessary data could be processed and made available in form and kind appropriate for usage in the methodology upon its acceptance as a standard practice.

Statement of the Problem

The overall problem may be posed as follows:

Given

1. The economic structure of a country by way of an input-output table,
2. Its long-range national economic development (NED) objectives and strategies,
3. The potential capabilities (and limitations) of its water and related resources (including capital);

select the water resources projects to be implemented during subsequent plan periods for the optimal realization of the stated objectives.

Basic Data

Economic Structure of the Country

The input-output tables for Pakistan economy for the years 1954 and 1963/64 prepared by G. Rasul (1964) and W. Tims (1965), respectively, were used in conjunction with other census material (Government of Pakistan, 1968 [a,b], 1970) to produce the input-output table depicted in Table V-1 and used as the simulator of the economy of the country of the example problem.

A water resources sector, disaggregated into three major subsectors, is added to the conventional input-output table. This is done in order to facilitate the assessment of the direct and indirect demands for the outputs of water resources projects. Census and other Government publications (Government of Pakistan, 1965, 1968 [a,b] 1970) have been used in the estimation of the transactions of the water resources sector with the other sectors of the economy.

Notice the absence of a separate government column in the Final Demands Sector (for identification of notations see Fig. IV-2). This is characteristic of developing countries where, by virtue of the fact that the government is involved in almost all sectors to a large extent, separate record keeping is practically impossible.

NED Objectives and Strategies

Here again, the long range (20 years) objectives and strategies of the Pakistani Government as stated in its "Long-Term Perspective Plan" and reproduced in its Third Five Year Plan (1965-70) (Government of Pakistan, 1965 [b]) is adopted to be the NED objectives and strategies of the example country.

The NED objectives: The objectives of the Perspective Plan are:

1. A quadrupling of the Gross National Product;
2. Provision of full employment to the entire labor force by about the middle of the Perspective Plan period;
3. Parity in per capita income between regions;
4. Universal literacy; and
5. Elimination of dependence on foreign assistance.

The main instrument for achieving the foregoing objectives is stated to be a fast rate of increase in Gross National Product--an average growth rate of 7.2 percent over the plan period. The basic framework of the long-term growth is given in Table V-2.

Growth strategies: The major strategies chosen are: moderate increases in gross investment; decrease in investments requiring foreign assistance; substantial increase in exports; and considerable import substitution in capital goods and intermediate products whose domestic production is projected to increase at the rate of 10.0 and 13.7 percent per annum, respectively.

The entire strategy in general, and the projection of increased production of capital goods and intermediate products at such a very high level in particular, is intended to effect significant structural changes of the economy of the country--from basically agricultural to one that is diversified, from one of net capital importing to self supporting.

A quantitative breakdown of the strategies is given in Tables V-3 and V-4 while the desired structural changes are stipulated in Table V-5. For further details refer to the long-term Perspective Plan in the Third Five Year Plan of Pakistan (Government of Pakistan, 1965).

The guidelines stated in Tables V-2 through V-5 were used in projecting the final demand and import levels given in Tables V-6 and V-7, respectively, for further use in the assessment of total demands and determination of incremental production requirements in successive plan periods (Appendix A). The aggregate sectors specified in Tables V-2 through V-5 are interpreted and disaggregated in terms of the sectors used in the input-output table.

Table V-1

Input-Output Table of the Example Country
(in millions)

	Group	Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		Agriculture & Forestry	1551.75	753.35			0.86			11728.20	0.13	1.72	1249.25	2056.94	15.90	186.96
2		Animal Husbandry	662.12	211.56			28.29							8.47	33.24	
3		Mining and Quarrying		34.68		113.66	2.39				0.96					8.15
4		Fuel & Power	35.00		1.45	4.84	2.20	1.44	1.21	1.63	0.29	0.15	4.16	31.19	13.59	4.86
5		Chemical Industry	78.54		3.73	3.39	0.56			3.55	2.97	0.22		4.09	122.29	39.08
6	Heavy Industries	Basic Metal						11.33	.86	23.62	6.18					
7	Heavy Industries	Machinery				13.29		0.28	52.14	0.68	0.09			0.52	1.95	
8	Heavy Industries	Others (Smithies)	62.70					9.70	49.42	838.74		0.69		23.03	2.41	
9	Heavy Industries	Non-Ferrous Products										0.48				
10	Heavy Industries	Wood-work					0.97	0.99	2.25	5.35	0.83		8.00	0.43	1.81	
11		Agricultural Process	53.36							15.35				278.80	421.50	
12		Food Industries		131.24			3.17							3.76	35.08	
13		Other Consumer Goods								43.02					804.81	
14		Paper & Printing Ind.					3.33			0.96	0.18	0.12	44.07	73.98	25.29	41.19
15		Construction	542.05													
16	Water Resources	M & I Water Supp.	0.26		45.97	126.69	109.20	37.43	118.87	48.46	5.53	1.82	195.34	543.58	203.72	87.93
17	Water Resources	Irrigation "	141.20													
18	Water Resources	Hydroelectric	5.60	4.10	1.69	2.48	1.63	0.97	0.85	1.09	0.06	0.06	1.82	10.90	9.69	4.24
19		Services	189.75	718.98	22.40	148.44	167.07	119.79	92.65	1242.49	6.39	30.57	450.63	657.49	585.49	229.58
		Total Intermediate Inputs	3322.33	1853.94	75.24	483.17	316.67	181.93	318.93	13953.14	20.64	35.83	1953.30	3676.60	2276.77	602.00
		Payments	27194.61	4937.05	212.56	216.17	500.75	531.42	2516.18	21.25	11.83	21.83	527.63	1836.66	1200.93	328.98
		Total Gross Outlays	30516.94	6790.99	287.80	699.34	818.42	533.35	2834.43	13974.39	32.47	57.66	2480.93	5513.26	3477.70	930.98

	Group	Sectors	15	16	17	18	19	W	C	I	E	M	Y	X	D	Z
1		Agriculture & Forestry	101.32				27.64	17674.05	10933.75		1236.31	672.83	12842.89	30516.94	29844.11	12170.06
2		Animal Husbandry					7.04	950.72	5557.13		205.75	77.39	5840.27	6790.99	6713.60	5762.88
3		Mining and Quarrying	28.46				0.26	188.56	47.13		13.23	46.17	99.24	287.80	241.63	53.07
4		Fuel & Power	7.54	6.26	0.21		48.39	162.20	499.07		4.80	33.27	537.14	699.34	666.07	503.87
5		Chemical Industry	35.73				63.39	357.53	342.06		28.19	90.64	460.89	818.42	727.78	370.25
6	Heavy Industries	Basic Metal	36.51					78.50	45.47	409.18	0.20		454.85	533.35	533.35	454.85
7	Heavy Industries	Machinery	65.83		0.14	15.60	17.03	167.55	689.34	822.73	18.39	1136.42	2666.88	2834.43	1698.01	1530.46
8	Heavy Industries	Others (Smithies)	460.33				9.27	1456.29	12408.99	30.69	30.86	47.56	12518.10	13974.39	13926.83	12470.54
9	Heavy Industries	Non-Ferrous Products					1.03	1.51	27.09		0.53	3.34	30.96	32.47	29.13	27.62
10	Heavy Industries	Wood-work	7.05				0.06	27.74	17.61		0.25	12.06	29.92	57.66	45.60	17.86
11		Agricultural Process						790.01	337.41	227.06	1120.39	6.06	1690.92	2480.93	2579.50	1684.86
12		Food Industries	0.98				25.50	199.73	5230.57		27.00	82.96	5313.53	5513.26	5434.71	5230.57
13		Other Consumer Goods					3.97	851.80	2363.99	10.00	217.73	34.18	2625.90	3477.70	3443.52	2591.72
14		Paper & Printing Ind.	38.21				103.92	333.42	238.91		326.90	31.75	597.56	930.98	899.23	565.81
15		Construction	617.70		4.10	5.60	600.13	1769.60		2437.01	1.15	14.37	2452.53	4207.16	4192.79	2438.16
16	Water Resources	M & I Water Supp.	471.87			31.21	7.96	2025.79	2260.29				2260.29	4286.08	4286.08	2260.29
17	Water Resources	Irrigation "						141.20						141.20	141.20	
18	Water Resources	Hydroelectric	4.24	7.34	21.11	4.54	8.99	91.40	10.10				10.10	101.50	101.50	10.10
19		Services	604.50	445.40	5.82	19.23	1444.41	7181.28	1171.19				1171.19	8891.45	8891.45	1171.19
		Total Intermediate Inputs	2480.29	459.00	31.38	76.18	2368.98									
		Payments	1726.87	3827.08	109.82	25.32	6522.47									
		Total Gross Outlays	4207.16	4286.08	141.20	101.50	8891.45	34448.88	42180.10	3936.67	3231.68	2289.00	51603.06	86576.05	84396.09	49314.16

Table V-2

Basic Framework of Pakistan's Long-Term Growth
(1965-85)
(Rs. Million; 1964-65 prices)

	1965	1970	1975	1980	1985	1965-85 (annual compound rate of growth) %
A. Key Magnitudes						
1. Gross national product (market prices)	45,540	62,765	89,815	129,690	187,300	7.2
2. Gross investment	8,400	12,700	19,180	28,650	42,800	8.5
3. Gross domestic savings	4,710	8,515	15,180	26,150	40,800	11.4
4. External resources	3,690	4,185	4,000	2,500	2,000	-3.0
5. Exports	3,050	4,800	7,300	11,000	14,000	7.9
6. Imports	6,990	8,985	11,300	13,500	16,000	4.2
B. As a % of the GNP						
1. Gross investment	18.4	20.2	21.4	22.1	22.9	
2. Gross domestic savings	10.3	13.6	16.9	20.2	21.8	
3. External resources	8.1	6.6	4.5	1.9	1.1	
4. Exports	6.7	7.6	8.1	8.5	7.5	
5. Imports	15.3	14.2	12.6	10.4	8.6	
C. Key Assumptions						
1. GNP growth rate (%)	5.2	6.5	7.3	7.5	7.5	7.2
2. Population growth rate (%)	2.6	2.7	2.8	2.6	2.1	2.6
3. Marginal rate of savings (%)	22	22	25	28	25	25
4. Capital-output ratio (gross)	2.8	2.9	2.9	2.9	3.0	2.9
5. Marginal propensity to import (%)		12	9	6	4	6

Source: Third Five Year Plan (Government of Pakistan, 1965)

Table V-3

Growth Pattern in the Perspective Plan

(Million Rs.; 1964-65 prices)

	1965	1970	1985	Annual compound rate of growth (1965-85) %
1. Agriculture	21,055	26,870	62,500	5.6
2. Manufacturing	5,195	8,365	36,500	10.2
(a) Consumer goods	(3,235)	(4,515)	(13,000)	(7.2)
(b) Intermediate products	(1,620)	(3,300)	(21,200)	(13.7)
(c) Investment goods	(340)	(550)	(2,300)	(10.0)
3. Other sectors	17,115	24,165	75,300	7.7
	43,365	59,400	174,300	7.2

Table V-4

Balance of Payments in the Perspective Plan
(Million Rs.; 1964-65 prices)

	1965	1970	1975	1980	1985	Annual compound growth rate (1965-85)
1. Exports	3,050	4,300	7,300	11,000	14,000	7.9
2. Imports	6,990	8,985	11,300	13,500	16,000	4.2
(a) consumer goods	1,830	2,025	2,220	(2,500)	(3,000)	2.5
(b) capital goods	2,015	2,840	4,300	(5,500)	(6,500)	6.0
(c) intermediate products	3,145	4,120	4,780	(5,500)	(6,500)	3.7
3. Balance of payments (deficit 2-1)	3,940(2)	4,185	4,000	2,500	2,000	-3.5
4. Percentage of total imports financed from own exports	44	53	65	82	88	

Table V-5

Structural Changes in the Perspective Plan
(Percentages; 1964-65 prices)

	1950	1965	1970	1985
1. Output	100	100	100	100
(a) agriculture	60	49	45	36
(b) manufacturing	6	12	14	21
(c) other sectors	34	39	41	43
2. Employment	100	100	100	100
(a) agriculture	75	65	62	49
(b) manufacturing		11	12	14
(c) other sectors	25	24	26	37

Source: Tables V-2 through V-5 are taken from Third Five Year Plan (Government of Pakistan, 1965).

Table V-6

Projected Final Demands
(in millions)

Sector[1]	Final Demands $(Y_{i\tau})$					Average annual compound rate of growth %
	0	1	2	3	4	
1	12843.00	16865.00	22148.00	29084.00	38193.00	5.60
2	5840.00	7669.00	10071.00	13225.00	17367.00	5.60
3	99.00	159.00	257.00	414.00	666.00	10.00
4	537.00	1022.00	1946.00	3704.00	7050.00	13.70
5	461.00	878.00	1670.00	3180.00	6052.00	13.70
6	455.00	866.00	1649.10	3138.00	5973.00	13.70
7	2667.00	4295.00	6917.00	11140.00	17942.00	10.00
8	12518.00	18142.00	26294.00	38107.00	55229.00	7.70
9	31.00	59.00	112.00	214.00	407.00	13.70
10	30.00	43.00	63.00	91.00	132.00	7.70
11	1691.00	2394.00	3390.00	4800.00	6796.00	7.20
12	5314.00	7524.00	10653.00	15084.00	21358.00	7.20
13	2626.00	3718.00	5265.00	7454.00	10554.00	7.20
14	598.00	867.00	1256.00	1820.00	2638.00	7.70
15	2453.00	3951.00	6362.00	10247.00	16502.00	10.00
16	2260.00	3640.00	5862.00	9440.00	15204.00	10.00
17	--	--	--	--	--	10.00
18	10.00	16.00	26.00	42.00	67.00	10.00
19	1171.00	1697.00	2460.00	3565.00	5166.00	7.70
GNP	49314.00	69168.00	98399.00	141296.00	202894.00	7.20

[1]Refer to Table V-1 for sector identification.

1. Agriculture includes sectors 1 and 2
2. Consumer goods includes sectors 11 through 13
3. Intermediate products includes sectors 4 through 6, and 9
4. Investment goods includes sectors 3, 7 and 15 through 18
5. Others include sectors 8, 10, 14, and 19

Resource Capabilities

The resources considered and incorporated in the mathematical model are capital, land and potential water resources project outputs.

Capital: The budgetary allocation for water resources development of Pakistan has been adopted to be the capital resource for the first and second plan periods (Government of Pakistan, 1970) with further extrapolation of the third and fourth.

Plan Period (τ)	Budget $(\bar{c}_\tau)$ (in millions)
1	9,965
2	15,965
3	35,930
4	61,081

Table V-7

Projected Import Levels
(in millions)

Sector[2]	Average annual compound rate of increases %	Imports $(M_{i\tau})$				
		0	1	2	3	4
1	4.20	673.00	827.00	1016.00	1248.00	1533.00
2	4.20	77.00	95.00	116.00	143.00	175.00
3	6.00	46.00	62.00	82.00	110.00	148.00
4	3.70	33.00	40.00	47.00	57.00	68.00
5	3.70	91.00	109.00	131.00	157.00	188.00
6	3.70	--	--	--	--	--
7	6.00	1136.00	1520.00	2034.00	2122.00	3643.00
8	4.20	48.00	59.00	72.00	89.00	109.00
9	4.20	3.00	4.00	5.00	6.00	7.00
10	4.20	12.00	15.00	18.00	22.00	27.00
11	2.50	6.00	7.00	8.00	9.00	10.00
12	2.50	83.00	94.00	106.00	120.00	136.00
13	2.50	34.00	38.00	44.00	49.00	58.00
14	4.20	32.00	39.00	48.00	59.00	73.00
15	6.00	14.00	19.00	25.00	34.00	45.00
16	6.00	--	--	--	--	--
17	6.00	--	--	--	--	--
18	6.00	--	--	--	--	--
19	6.00	--	--	--	--	--

[2]Refer to Table V-1 for sector identification.

Water and related resources: The potential water resources projects in this hypothetical case are surface water from three major rivers which are primarily for irrigation and power, and groundwater development which is mainly for M & I water supply. The information about the projects is by and large real and is borrowed from feasibility studies of projects in Turkey (Republic of Turkey, 1970), and Pakistan (World Bank Study Group, 1969) with some alteration made to more fully display the application of the methodology.

The projects are schematically depicted in Figs. V-1 through V-3 and the date necessary for use in the selection and timing model are given in Table V-8.

Important project interrelationships are as follows:

River basin I:

Contingent projects:

3 upon 2	13 upon 12	20 upon 19
5 upon 3	15 upon 13	
6 upon 4	16 upon 14	
7 upon 2	17 upon 12	

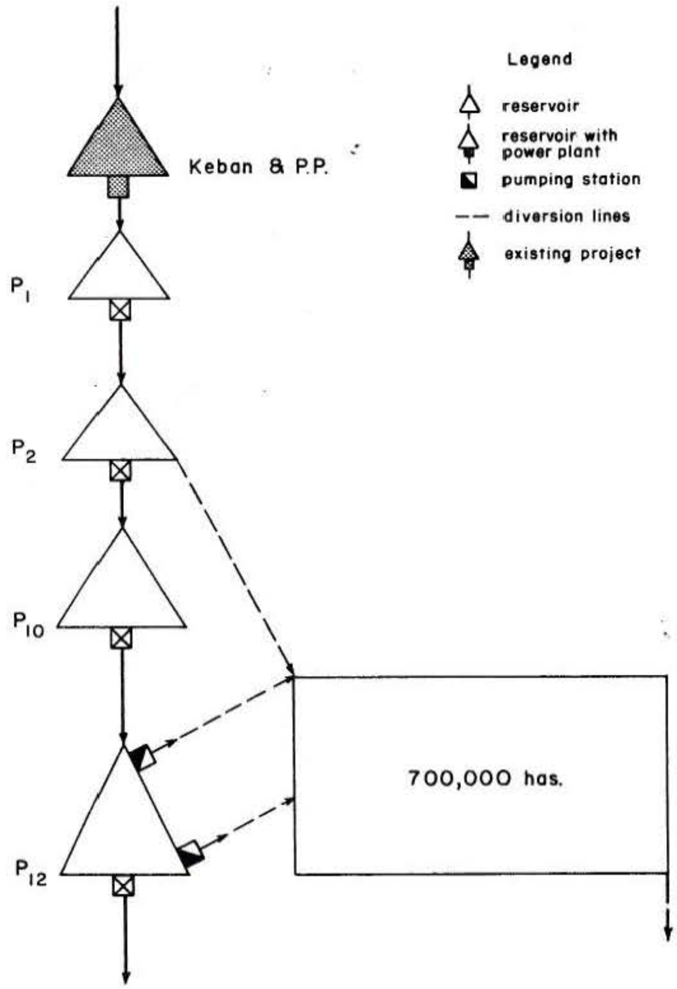


Fig. V-1. River Basin I.

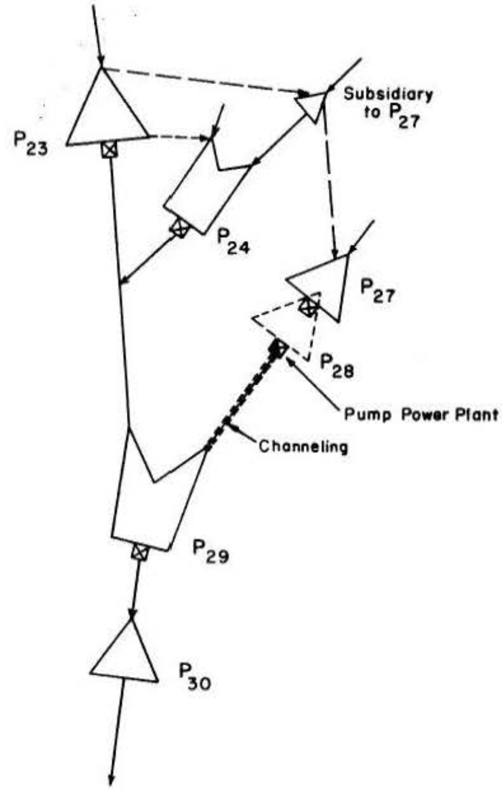


Fig. V-2. River Basin II.

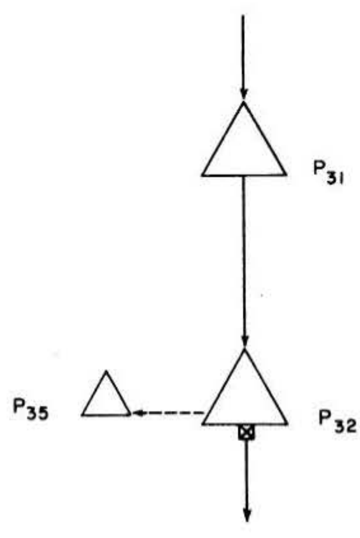


Fig. V-3. River Basin III.

Table V-8

Data on Water Resources Projects

P_k	Stage and combination index	Descriptions	Values of Project outputs (in millions)						Project maturation Time	Compound amounts of costs and net worths of Projects at the begining of plan periods @ 8% per annum. (in millions)					
			Average annual			Present worth				=2		=3		=4	
			M&I b_1	Irrigation b_2	Power b_3	Total Benefits B	Total costs C	Net S	T yrs.	c_{k2}	s_{k2}	c_{k3}	c_{k3}	c_{k4}	s_{k4}
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		Projects From River Basin I													
1		Karakaya			347	4924	2243	2618	9	3296	3847	4842	5652	7115	8304
2	2.1	Low Tasustu			173	2462	1669	793	5	2452	1165	3603	1712	5294	2515
3	2.1.1	add $4x10^5$ has. to P_2 by pump irrigation		604	2	8546	5186	3360	2	7620	4937	11196	7254	16450	10658
4	2.2	P_2 & P_3 combined		604	171	11008	6855	4153	5	10072	6102	14799	8966	21744	13173
5	2.1.2	add $3x10^5$ has. to P_3		451	1	6424	5876	548	2	8634	805	12685	1183	18639	1738
6	2.2.1	add $3x10^5$ has. to P_4		451	1	6424	5876	548	2	8634	805	12685	1183	18639	1738
7	2.1.3	add $7x10^5$ has. to P_2		1055	1	14970	11062	3902	3	16253	5733	23881	8424	35089	12377
8	2.3	P_2 & P_7 combined		1055	172	17432	12731	4701	5	18706	6907	27484	10149	40383	14912
9		High Tasustu		947	443	19735	11397	8338	8	16746	12251	24604	18000	36151	26448
10		Low Golkoy			97	1370	688	682	4	1011	1002	1485	1472	2183	2163
11		High Golkoy		947	399	19115	17806	1309	7	26162	1923	38440	2826	56480	4152
12	12.1	Low Karababa			121	1748	1476	269	5	2169	395	3164	581	4682	853
13	12.1.1	add $3x10^5$ has. to P_{12}		453	1	6422	4616	1806	2	6782	2654	9965	3899	14641	5729
14	12.2	P_{12} & P_{13} combined		453	122	8170	6092	2078	5	8951	3053	13152	486	19324	6591
15	12.1.2.	add $4x10^5$ has. to P_{13}		604	2	8600	4701	3899	2	6907	5729	10148	8417	14912	12368
16	12.2.1	add $4x10^5$ has. to P_{14}		604	2	8600	4701	3899	2	6907	5729	10148	4817	14912	12368
17	12.1.3	add $7x10^5$ has. to P_{12}		1057	3	15022	9317	5705	3	13689	8382	20114	12316	29553	18096
18	12.3	P_{12} & P_{17} combined		1057	124	16770	10793	5977	5	15858	8782	23300	12903	34235	18959
19	19.1	Middle Karababa			177	2518	1979	539	6	2908	792	4272	1164	6277	1710
20	19.1.2	add $7x10^5$ to P_{19}		1057	16	15233	9127	6106	3	13410	8972	19704	13182	28951	19368
21	19.2	P_{19} & P_{20} combined		1057	193	17751.	11106	6645	6	16318	9763	23976	14346	35228	21078
22		High Karababa		949	262	17191	11338	5853	8	16659	8600	24477	12636	35964	18566
		Projects From River Basin II													
23		Tarbela		224	53	3353	1885	1468	10	2770	2157	4069	3169	5979	4656
24	24.1	Low Gariala (side storage from Tarbela)		78	26	1600	1200	400	5	1763	587	2591	864	2806	1269
25	24.1.1	Raise P_{24}		123	28	1725	1045	680	4	1535	999	2256	1468	3315	2157
26		High Gariala (P_{24} & P_{25} combined)		201	54	3325	2102	1223	7	3088	1797	4538	2640	6668	3879
27		Dhok Pathan (side storage from Tarbela)		53	213	3250	2575	675	8	3783	992	5559	1457	8168	2141
28		Dhok Abbaki (pumped storage from Kalabagh)		52	209	3200	2500	700	7	3673	1029	5397	1511	7930	2220
29		Kalabagh	1451	216	54	21051	10996	10055	9	16156	14773	23739	21707	34879	31894
30		Kattema	2500			30583	20983	96001	5	30830	14105	45299	20725	66558	30451
		Projects From River Basin III													
31		Pictar	2740			33530	18850	14680	10	27696	21569	40694	31692	59792	46565
32	32.1	Mangla	78		26	1600	1150	1485	4	1690	2182	2483	3206	3648	4710
33	32.1.2	Raise P_{32}		123	28	1725	1040	685	3	1528	1006	2245	1479	3299	2173
34		High Mangla	78	123	54	3325	2050	1275	6	3012	1873	4426	2753	6503	4044
35		Rohtas (side storage from Mangla)	1500			1835	9240	9110	3	13576	13385	19948	19667	29309	28897
		Ground Water Projects													
36		Shorkot Kamalia		16		159	72	87	4	106	128	155	188	228	276
37		Rohri North	340			3290	1890	1440	6	2777	2116	4080	3109	5995	4568
38		Ponjnad Abbasia	610			5970	2520	3450	4	3703	5069	5440	7448	7993	10943
39		Shujaabad		26		259	65	194	4	96	285	140	419	206	615
40		Ravi Syphon Div.	306			3009	686	2323	4	1008	3413	1481	5015	2176	7369
41		Rohri South	348			3417	1465	1952	5	2153	2868	3163	4214	4647	6192
42		Bahwal Qaim	900			8837	5701	3136	4	1712	4608	2515	6770	3695	9947
43		Fordwah Sadiqia	308			3023	832	2191	5	1222	3219	1796	4730	2639	6950
44		Begari Sind		18		180	111	69	5	163	101	240	149	352	219
45		Sukkur R. Bank		18		178	102	76	5	150	112	220	164	324	241

Mutually Exclusive Projects:

2 and 4	12 and 14	21 and 18
2 and 8	12 and 18	21 and 14
2 and 9	13 and 17	21 and 12
4 and 8	14 and 18	22 and 19
3 and 7	12 and 19	22 and 21
9 and 8	19 and 14	22 and 12
9 and 4	19 and 18	22 and 14
	21 and 19	22 and 18

Land Resource Limitation:

There are only 700,000 has. of irrigable land in this river basin. This fact is incorporated in the selection and timing model by requiring that the total irrigation benefits from all the projects in this river basin do not exceed the potential maximum revenue from all the irrigable land.

River basin II:

Contingent projects:

24 upon 23

25 upon 24

26 upon 23

27 upon 23

28 upon 29

Mutually exclusive projects:

24 and 27

24 and 26

27 and 28

River basin III:

Contingent projects:

33 upon 32

35 upon 32

or 35 upon 34

Mutually exclusive projects:

32 and 34

Compulsory precedence by at least one time period:

The following projects cannot be implemented unless at least one plan period has elapsed after the implementation of projects they are contingent upon (refer to Table V-8).

25 upon 24

33 upon 32

Such relationships frequently occur when parellel implementation of a pair of contingent projects is impossible. The following set of expressions are designed to ensure observance of such interdependencies among pairs of contingent projects and facilitate correct selection without eliminating any possible choice (n is the number of periods that must elapse between the construction of projects j and k).

$$\begin{aligned} &P_{k\tau} - \sum_{\tau=1}^{N} P_{j(\tau-n)} \leq 0 \\ &P_{k\tau} + P_{j\tau} \leq 1 \\ &P_{k\tau} - \sum_{\tau=1}^{N} P_{j(\tau+n)} \leq 0 \\ &P_{k(\tau+n)} + P_{j(\tau+n)} \leq 1 \end{aligned} \qquad (5\text{-}1)$$

The groundwater projects are independent of each other.

Assessment of Production Requirements

The elements of the final demand vector were projected in accordance with the development plan objectives and strategies and presented in Table V-6. The projected final demand vector for each plan period was further used in assessing the direct and indirect requirements for outputs and services of the different sectors of the economy as well as that of the water resources sector.

A computer program has been developed for the projection of the input-output table and for the assessment of incremental production requirements for project outputs of goods and services in subsequent plan periods. The program code as well as its input and output printouts are included in Appendix A.

Selection and Timing of Projects

The mathematical model developed in Chapter IV is employed for selecting projects to be implemented prior to the start of the plan periods so as to provide the direct and indirect requirements for the outputs and services of the water resources sector by all sectors of the economy in order to meet the long range development objectives and targets. Of course, it is to be done within the constraints of capital, land and other resources.

Solution Algorithm Employed

Known techniques for solving the general zero-one integer linear programming problem that could possibly be tried for solving the mathematical problem at hand include Balas' (1965, 1967) additive improved version of Balas' by Lemke and Spielberg (1967) called DZIP; Geoffrion's (1968, 1969) RIP30C that is based on an implicit enumeration algorithm utilizing a strongest surrogate constraint which is very similar to that developed by Glover (1965); and cutting plane algorithms, including that of Lawler and Bell (1966). These are only a few of the ever growing number of algorithms reported in the literature. For a more complete summary of zero-one integer programming algorithms, refer to Gue et al. (1968) and Geoffrion and Marsten (1972). Despite the fact that the number of algorithms reported to exist is large and ever growing, they are not readily available for applied use.

Of the many algorithms developed for solving zero-one integer (all or mixed) programming problems, most of the reports on computational experience (Peterson, 1967; Trauth and Woolsey, 1969; Gue et al., 1968; Geoffrion and Marsten, 1972; Pettway, 1973) show that Geoffrion's enumerative algorithm with surrogate constraints is superior to all the others for the range of problems to which they were applied.

Pettway's study (1973) led to the conclusion that of the more available integer linear programming algorithms, enumerative (implicit) types converged faster than the cutting plane types and that the algorithms of Lemke and Spielberg (1967) and Geoffrion (1968) were the best of those studied by him--mainly small size problems of which the largest was 25 x 28. The other studies (Gue et al., 1968; Geoffrion, 1969; Geoffrion and Marsten, 1972) firmly conclude, based on studies involving greater numbers and larger problems than used by Pettway, that Geoffrion's RIP30C is superior to all as the fastest converging algorithm and assert that the necessary solution time has a polynomial relationship with the number of variables while this is an exponential relationship in the other algorithms.

The studies made so far do not make an exhaustive inquiry into computer storage requirements as related to the size of problems and algorithms used. This is a matter that deserves investigation since in an n-variable zero-one problem there may be as many as 2^n possible solutions. Furthermore, the consensus among experimenters is that these algorithms are characterized by large computer space requirements and that there is little hope of solving problems with more than 100 variables in a reasonable amount of machine time. This concern is strongly expressed in the article by Gue et al. (1968). They also hold the view that Geoffrion's algorithm is the most promising for handling large problems with possibly some further improvements.

Therefore, since all evidences seem to indicate that Geoffrion's algorithm RIP30C, is the best, it is chosen for solving the problem in this study.

Necessary problem manipulations: RIP30C is written to solve integer linear programs of the following form:

$$\begin{aligned}&\text{minimize } cx\\&\text{subject to } Ax + b \geq 0\\&\qquad\qquad x_j = 0 \text{ or } 1\end{aligned}$$

in which c and x are N-dimensional vectors, b is an M-dimensional vector, and A is an MxN matrix.

Any bounded integer program can be reformulated to conform to the given form using elementary manipulations such as the following.

The objective function: If the problem is a maximization problem, which is the case of the example problem, the objective function (but not the constraints) must be multiplied by -1. This follows from the fact that the maximum of any function f is the minimum of $-f$.

The constraints: The algorithm requires that all the elements of [A] as well as the constraint vector b be put on the left side of the inequality sign.

Inequalities of the sense $g_i \leq 0$ are changed to $g_i \leq 0$ by multiplying by -1.

Equality constraints must be replaced by two inequality constraints of different sense and the one with the sense of $g_i \leq 0$ multiplied by -1. That is, given $g_i = 0$, proceed as follows:

$$g_i = 0 \Rightarrow \begin{cases} g_i \geq 0 \\ g_i \leq 0 \end{cases} \Rightarrow \begin{cases} g_i \geq 0 \\ -g_i \geq 0 \end{cases} \Rightarrow \begin{cases} g_i \geq 0 \\ g_j \geq 0 \end{cases}$$

in which $g_j \triangleq -g_i$.

Results and Analysis

In order to ensure global optimality of the solution to the foregoing problem, it should be treated in its entirety, i.e., include all the variables (45) and for the entire number of plan periods (4). The solution then will represent an optimum water resources program that is tailored to ensure a sustained national economic development for a future time span of twenty years according to the desired rate and strategy given in the national long-range development plan.

But, as if designed to substantiate Messrs. Gue and associates' fear that the algorithms require large storage space and may be impossible to be used in solving large problems (Gue et al., 1968), it turned out that the presently formulated problem is too large for the CDC6400 computer available at Colorado State University, with an operating core space of $140{,}000_8$. The size of the constraint matrix is 244 x 180 and it is much larger than what the algorithm had been applied to, according to available information. The problem became excessively large, even though the number of decision variables are only 45, for two fundamental reasons: 1) It is a combinatorial problem. 2) Imbedded in its linear appearance, it has dynamic aspects accounting for several time periods by replicate constraints (see Table V-9).

Table V-9

Effect of Dynamic Aspect of the Selection and Timing Problem in its Size

No. of Plan Periods	No. of Variables	No. of Possible Solutions
1	45	3.5×10^{13}
2	90	1.2×10^{27}
4	180	1.5×10^{54}

The problem can be made amenable for solution by employing a suitable solution strategy technique.[3] At this moment the most suitable technique appears to be the Dantzig-Wolfe decomposition technique which is

[3]"Solution strategy" techniques reduce an optimization problem to a related sequence of simpler optimization problems as opposed to "problem manipulation" techniques which are devices for restating a given problem in an alternative form that is apt to be more amenable to solution. (For detailed explanation refer to Geoffrion, 1969).

best suited to problems with a large number of both variables and constraints. This procedure is most efficient when applied to linear programs whose coefficient matrices have block-diagonal structure linked with coupling equations (Lasdon, 1970). The other attractive feature of this technique is the fact that it does not require much computer storage since the intermediate steps (column generation) require almost no storage space (Lasdon, 1970).

Despite the fact that the technique appears to be tailor-made to alleviate the difficulty encountered by the example problem, it could not be used in this study as there is no computer code available which is based on the Dantzig-Wolfe decomposition algorithm to solve a zero-one integer linear programming problem. Although it is an interesting area for further study, it is beyond the scope and objective of the present study to develop such a code.

The purpose of this chapter, as stated at the beginning, is to illustrate the mechanics of each procedure and step of the methodology on an example problem that is as close to the real world situation as circumstance can allow it to be made. This goal can be achieved by simply reducing the size of the problem.

Reducing the size of the problem in this case means either reducing the number of variables (number of project proposals) or reducing the number of plan periods (the time horizon). The logical choice would be to reduce the number of plan periods, while making the rather evident assumption that the project selection and timing is an exercise to be repeated and updated periodically, rather than reducing the number of alternatives which would seriously compromise demonstration of details in this study and would be an unrealistic course of action when seen in the light of real world situations.

Results: The available computer storage capacity would barely permit solving the problem for two plan periods whose constraint matrix is (134 x 90) which in this case amounts to a span of ten years.

The computer program is given in Appendix B. A summary of the result is given in Table V-11.

Special findings: Solving the problem for only the first plan period and then for two consecutive periods simultaneously resulted in two different sets of projects for the first plan period indicating that separate piecewise solution could lead to a nonoptimal solution. The two solutions are given in Appendix C.

For some reason, Geoffrion's algorithm of implicit enumeration with surrogate constraints could not produce a solution to the two time period problem, although it did for the one time period. But the option available in RIP30C of the implicit enumeration algorithm (the Balas algorithm), without the use of the imbedded linear program to solve the surrogate constraints, did solve the problem, although it took more computer time than the former would have taken.

On the practical side, it was learned that the allocated budget of 15965×10^6 (Rps) for water resources development in the second plan period is grossly inadequate while that of 9965×10^6 (Rps) allocated for the first plan period is excessive by a fair amount. By trial and error, the necessary budget for water resources development was found to be 7634×10^6 and 47525×10^6 (Rps) for the first and second plan periods, respectively.

The initial trials led to raising the budget allocation for the second plan period to $50,000 \times 10^6$ resulting in an optimal solution summarized in Table V-10. A study of the table reveals that the power supply in the first plan period and that of both power and irrigation water in the second are provided for more than three hundred percent by the selected projects. It may be possible to remove some of the projects without compromising the demand targets and thereby making a cut in the budget.

Based on the study of the balance of supply and demand, it seems possible to exclude project number 2 from the first plan period and projects 28 and 36 from the second. This may be achieved by cutting the budget to $b_{4,1} = 7634 \times 10^6$ and $b_{4,2} = 45542 \times 10^6$ for the respective plan periods. This trial proved to be infeasible. A further inquiry revealed that project number 28 could not be excluded since project number 29 is contingent upon it. The latter also has to be included in the selection for the second plan period in order to satisfy the M&I water supply requirement as there is no other set of projects that could produce as much (see Table V-8). The next logical trial is to exclude projects number 32 and 36 from the second plan period by setting $b_{4,2} = 47525 \times 10^6$. The result, which happens to be the final water resources development program for the example country, is summarized in Table V-11.

The highest demand and the tightest provision of the selected program is for M&I water supply which could not tolerate more than 2 (1.7 to be exact) and 8 (8.3) percent possible increase over the estimated demands for the first and second plan periods, respectively.

The supply of irrigation water could tolerate an increase of demand over that projected of up to 11 percent in the first plan period while that of power may double. The supply of these outputs is more than 300 percent more than what is projected for the second plan period. This is primarily due to the inseparability of projects number 28 and 29 under the existing circumstances. Therefore, a strong recommendation should be made to initiate an intensive investigation for a potential independent single purpose project (or one with power--but this is not a requirement since there are feasible projects that could supply the necessary power demand) that could match the M&I water supply output capacity of project number 29 which would certainly cost less than projects number 28 and 29 combined.

Table V-10

Summary of the First Selection Results

	Average Annual Values of Project Outputs (10^6)											
	I Plan period (τ = 1)										Total	Target
Selected projects	2	10	38	39	40	41	42	43	44	45		
M&I water (b_1)	---	---	610	---	306	348	900	308	---	---	2472	2430
Irrigation (b_2)	---	---	---	26	---	---	---	---	18	18	62	54
Hydropower (b_3)	173	97	---	---	---	---	---	---	---	---	270	48
Project cost (b_4)	1669	688	2520	65	686	1465	1165	832	111	102	9303	9965
Project maturity time (T)	5	4	4	4	4	5	4	5	5	5		5
	II Plan period (τ = 2)											
Selected projects	28	29	31	32	36							
M&I water (b_1)	---	1451	2740	78	---						4269	3866
Irrigation (b_2)	52	216	---	---	16						284	76
Hydropower (b_3)	209	54	---	26	---						289	73
Project cost (b_4)	3673	16156	27696	1690	1060						48747	50000
Project maturity time (T)	7	9	10	4	4							10

Table V-11

Summary of the Final Selection Results

	Average Annual Values of Project Outputs (10^6)										
	I Plan period (τ = 1)									Total	Target
Selected projects	10	36	38	39	40	41	42	43	45		
M&I water (b_1)	---	---	610	---	306	348	900	308	---	2472	2430
Irrigation (b_2)	---	16	---	26	---	---	---	---	18	60	54
Hydropower (b_3)	97	---	---	---	---	---	---	---	---	97	48
Project cost (b_4)	688	72	2520	65	686	1465	1165	832	102	7634	7634
Project maturity time (T)	4	4	4	4	4	5	4	5	5		5
	II Plan period (τ = 2)										
Selected projects	28	29	31								
M&I water (b_1)	---	1451	2740							4190	3866
Irrigation (b_2)	52	216	---							268	76
Hydropower (b_3)	209	54	---							263	73
Project cost (b_4)	3673	16156	27696							47525	47525
Project maturity time (T)	7	9	10								10

Chapter VI
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The case has been made that central planning is most desirable for balanced, accelerated, and sustained national economic development (NED) to take place. It is even inevitable if the ever widening gap between the developing and developed nations is to start closing.

Furthermore, projects that comprise sectoral programs, which in turn are subsets of the entire NED plan, should be selected on the basis of their contributions to the attainment of NED objectives and targets. Such pragmatic program formulation requires a methodology that utilizes quantitative analytical procedures to carry out the selection of projects that best accomplish the NED goals without overlooking available options and within the resource capabilities of a nation. Developing such a methodology has been the objective of this study. This objective has been fully achieved.

A methodology that provides for ample measures to incorporate all relevant considerations which are characteristic of water resources projects selection and timing to promote balanced and sustained economic development in centrally planned and coordinated framework (for details of the major consideration refer to p. III-3, Chapter III) has been developed. This makes the methodology far superior to present techniques.

The methodology is composed of several analytical procedures. The input-output model is used to simulate the economy of the country, in making consistent projections of the elements of final demands in accordance with NED objectives and strategies, and in assessing total and incremental requirements for sectoral outputs of goods and services in subsequent plan periods. A mathematical model is developed and zero-one integer linear programming is employed to make the selection of projects that yield an optimal water resources development program for the number of planning periods under consideration.

Application of the methodology on the example problem as a whole, and the points discussed under "Special findings" (Chapter V) in particular, indicate the capacity of the methodology to incorporate details and enable the performance of rigorous analysis which certainly makes it a very useful tool in the process of NED planning. Thus, applied carefully and judiciously it will improve the insight gained and hence the final decision reached regarding the selection and timing for implementation of water resources projects to promote NED. Furthermore, the methodology could in principle be applied to similar decision making in the other sectors of the economy provided that the necessary data in the appropriate kind and form are made available.

The only limitation on extended use of the methodology learned from the computational experience is the rather large computer storage requirement which becomes prohibitive when the selection and timing problem involves a large number of projects and several time periods. Further research efforts should be directed in developing new algorithms (or adopt existing ones such as the Dantzig-Wolfe decomposition algorithm) with efficient computer codes that use solution strategy techniques for abetting the dimensionality problems associated with large size problems.

Concomitant to the adoption of the methodology as a standard procedure in the national economic development planning process is the reorganization of the format and scope of the data collection and processing on national resources base and economic transactions. Water resources should be classified as a separate economic sector and included in the input-output table of the economy. Water resources project identification and studies up to and including feasibility reports should be carried out on a continuous basis.

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APPENDIX A: COMPUTER PROGRAM AND OUTPUTS OF INPUT-OUTPUT PROJECTION AND DETERMINATION OF PRODUCTION REQUIREMENTS

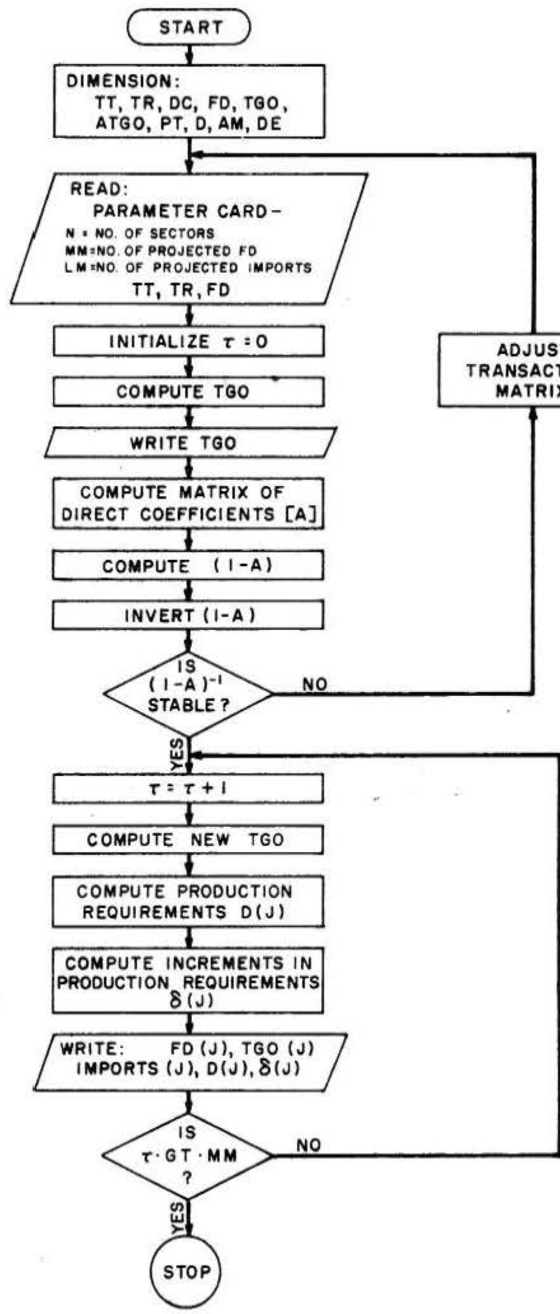

Fig. A-1 Flowchart for the Assessment of Production Requirements

```
      PROGRAM IO (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     NOTES
C     N=NUMBER OF SECTORS
C     MM=NUMBER OF PROJECTION PERIODS OR NUMBER OF FD VECTORS
C     KM=IMPO RTS
C     TT=TABLE TITLES
C     TR=TRAN SACTIONS MATRIX
C     DC= DIRECT COEFFICIENTS
C     TGO=TOTAL PRODUCTION REGUIREMENTS
C
C     DATA
C     CARD 1=N,MM,LM
C     PARAMETERS CARD START AT COLUMN 1
C     CARD 2-TITLE OF TABLES 80 COLUMNS
C     CARD 3 FORMAT OF TRANSACTIONS,8 (F L0.2)
C     CARD 4 NO. OF TRANSACTIONS CARDS TO BE READ
C     CARD 5 - FORMAT OF FD (8F10.2)
C     DATA CARDS
C     BLANK CARD
C
      DIMENSION TT(10), TR(40,40), DC(40,40), FD(40), TGO(40), ATGO(40),
     1 PT(40,40), D(40), AM(40), DE(40)
      READ (5,138) N,MM,LM
      L=0
      READ (5,139) (TT(I),I=1,10)
      READ (5,139) FMT
      DO 101 I=1,N
  101 READ (5,FMT) (TR(I,J),J=1,N)
      READ (5,139) FMT
      READ (5,FMT) (FD(I),I=1,N)
C
C     CALCULATE TOTAL OUTPUTS
C
      DO 102 I=1,N
        TGO(I)=FD(I)
      DO 102 J=1,N
  102 TGO(I)=TGO(I)+TR(I,J)
      IF (LM.NE.1) GO TO 104
      READ (5,FMT) (AM(I),I=1,N)
      DO 103 I=1,N
  103 D(I)=TGO(I)-AM(I)
  104 IN=N/10
      IF ((10*IN).EQ.IN) GO TO 105
C
C     WRITE OUT TRANSACTIONS TABLE
C
      IN=IN+1
  105 IM=1
      IF (IN.LT.1) IN=1
      DO 107 KK=1,IN
         WRITE (6,140)
         WRITE (6,141) KK,IN
         WRITE (6,142)
         KC=KK*10
         IF (KC.GT.N) KC=N
         WRITE (6,143) (I,I=IM,KC)
         DO 106 I=1,N
  106    WRITE (6,144) I,(TR(I,J),J=IM,KC)
         WRITE (6,142)
         IM=KC+1
  107 CONTINUE
      WRITE (6,146)
      DO 108 I=1,N
  108 WRITE (6,145) FD(I),TGO(I)
C
C     COMPUTE DIRECT COEFFICIENTS
C
      DO 109 J=1,N
      DO 109 I=1,N
  109 DC(I,J)=TR(I,J)/TGO(J)
C
C     WRITE DIRECT COEFFICIENTS
C
  110 IN=N/10
      IF ((10*IN).EQ.IN) GO TO 111
      IN=IN+1
  111 IM=1
      IF (IN.LT.1) IN=1
      DO 115 KK=1,IN
         IF (L.EQ.1) GO TO 112
         WRITE (6,147)
         GO TO 113
  112    WRITE (6,148)
  113    WRITE (6,141) KK,IN
         WRITE (6,142)
         KC=KK*10
         IF (KC.GT.N) KC=N
         WRITE (6,143) (I,I=IM,KC)
         DO 114 I=1,N
```

```
114     WRITE (6,149) I,(DC(I,J),J=IM,KC)
        WRITE (6,142)
        IM=KC+1
  115 CONTINUE
      IF (L.EQ.1) GO TO 124
C
C     COMPUTE I-A
C
      DO 116 I=1,N
      DO 116 J=1,N
         PT(I,J)=DC(I,J)
  116 DC(I,J)=-DC(I,J)
      DO 117 I=1,N
  117 DC(I,I)=1.0+DC(I,I)
C
C     INVERT I-A
C
      DC(1,N+1)=1.0
      DO 118 I=1,N
  118 DC(I+1,N+1)=0.0
      DO 121 KK=1,N
         DO 119 J=1,N
  119    DC(N+1,J)=DC(1,J+1)/DC(1,1)
         DO 120 I=2,N
         DO 120 J=1,N
  120    DC(I-1,J)=DC(I,J+1)-DC(I,1)*DC(N+1,J)
      DO 121 J=1,N
  121 DC(N,J)=DC(N+1,J)
C
C     DC NOW CONTAINS I-A INVERTED AND TRANSPOSED
C
      DO 122 I=1,N
         ATGO(I)=0.0
      DO 122 J=1,N
  122 ATGO(I)=ATGO(I)+DC(I,J)*FD(J)
      WRITE (6,150)
      DO 123 I=1,N
  123 WRITE (6,151) ATGO(I),TGO(I)
      L=1
      GO TO 110
  124 DO 136 I=1,MM
         READ (5,FMT) (FD(J),J=1,N)
         DO 125 L=1,N
            TGO(L)=0.0
         DO 125 J=1,N
  125    TGO(L)=TGO(L)+DC(L,J)*FD(J)
         IF (LM.NE.1) GO TO 131
         READ (5,FMT) ((AM(L),L=1,N))
C
C     TERMINATE READING DATTA
C
         IF (EOF(5)) 137,126,137
  126    CONTINUE
         DO 127 L=1,N
  127    ATGO(L)=TGO(L)-AM(L)
         DO 128 L=1,N
  128    D(L)=ATGO(L)-D(L)
         WRITE (6,152) (I,K=1,5)
         DO 129 L=1,N
  129    WRITE (6,153) L,FD(L),TGO(L),AM(L),ATGO(L),D(L)
         DO 130 L=1,N
  130    D(L)=ATGO(L)
  131    DO 132 J=1,N
         DO 132 L=1,N
  132    TR(L,J)=PT(L,J)*TGO(J)
         IN=N/10
         IF ((10*IN).EQ.IN) GO TO 133
         IN=IN+1
  133    IM=1
         IF (IN.LT.1) IN=1
         DO 135 KK=1,IN
            WRITE (6,154) I
            WRITE (6,141) KK,IN
            WRITE (6,142)
            KC=KK*10
            IF (KC.GT.N) KC=N
            WRITE (6,143) (L,L=IM,KC)
            DO 134 L=1,N
  134       WRITE (6,144) L,(TR(L,J),J=IM,KC)
            WRITE (6,142)
            IM=KC+1
  135    CONTINUE
  136 CONTINUE
  137 CONTINUE
      STOP
C
  138 FORMAT (3I2)
  139 FORMAT (10A8)
  140 FORMAT (1H1,///,10X, 18HTRANSACTIONS TABLE)
  141 FORMAT (100X,  4HPAGE,I2,1X,  2HOF,I2)
```

```
142 FORMAT (10X,123(  1H-))
143 FORMAT (10X,  6HSECTOR,4X,I2,9I10)
144 FORMAT (10X,I2,3X,10F10.3)
145 FORMAT (6X,2F15.3)
146 FORMAT (1H1,///,10X, 12HFINAL DEMAND,3X, 12HTOTAL OUTPUT)
147 FORMAT (1H1,///,10X, 19HDIRECT COEFFICIENTS)
148 FORMAT (1H1,///,10X, 32HDIRECT AND INDIRECT COEFFICIENTS)
149 FORMAT (10X,I2,3X,10F10.6)
150 FORMAT (1H1,///,10X, 38HCHECK, BOTH COLUMNS SHOULD BE THE SAME)
151 FORMAT (10X,2F12.3)
152 FORMAT (1H1,///,13X, 14HFINAL DEMANDS(,I2,  1H),2X, 14HTOTAL OUTPU
   1TS(,I2,  1H),5X,  8HIMPORTS(,I2,  1H),3X, 17HTOTAL PRODUCTION(,I2,
   2  1H),1X, 21HINCREASED PRODUCTION(,I2,  1H))
153 FORMAT (5X,I2,2F17.3,5X,2F17.3,5X,F17.3)
154 FORMAT (1H1,///,10X, 29HPROJECTED TRANSACTIONS TABLE(,I2,  1H))
    END
```

TRANSACTIONS TABLE

SECTOR	1	2	3	4	5	6	7	8	9	10
1	1551.750	753.380	0.000	0.000	.860	0.000	0.000	11728.200	.130	1.720
2	662.120	211.560	0.000	0.000	28.290	0.000	0.000	0.000	0.000	0.000
3	0.000	34.680	0.000	113.660	2.390	0.000	0.000	0.000	.960	0.000
4	35.000	0.000	1.450	4.840	2.200	1.440	1.210	1.630	.290	.150
5	78.540	0.000	3.730	3.390	.560	0.000	0.000	3.550	2.970	.220
6	0.000	0.000	0.000	0.000	0.000	11.330	.860	23.620	6.180	0.000
7	0.000	0.000	0.000	13.290	0.000	.280	52.140	.680	.090	0.000
8	62.700	0.000	0.000	0.000	0.000	9.700	49.420	838.740	0.000	.690
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.480
10	0.000	0.000	0.000	0.000	.970	.990	2.250	5.350	.830	0.000
11	53.360	0.000	0.000	0.000	0.000	0.000	0.000	15.350	0.000	0.000
12	0.000	131.240	0.000	0.000	3.170	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	43.020	0.000	0.000
14	0.000	0.000	0.000	0.000	3.330	0.000	0.000	.960	.180	.120
15	542.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.050	0.000
16	.260	0.000	45.970	126.690	109.200	37.430	118.870	48.460	5.530	1.820
17	141.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	5.600	4.100	1.690	2.480	1.630	.970	.850	1.090	.060	.600
19	189.750	718.980	22.400	148.440	167.070	119.790	92.650	1214.490	6.390	30.570

SECTOR	11	12	13	14	15	16	17	18	19
1	1249.250	2056.940	15.900	186.960	101.320	0.000	0.000	0.000	27.640
2	0.000	8.470	33.240	0.000	0.000	0.000	0.000	0.000	7.040
3	0.000	0.000	0.000	8.150	28.460	0.000	0.000	0.000	.260
4	4.160	31.190	13.590	4.860	7.540	6.260	.210	0.000	48.390
5	0.000	4.090	122.290	39.080	35.730	0.000	0.000	0.000	63.380
6	0.000	0.000	0.000	0.000	36.510	0.000	0.000	0.000	0.000
7	0.000	.520	1.950	0.000	65.830	0.000	.140	15.600	17.030
8	0.000	23.030	2.410	0.000	460.330	0.000	0.000	0.000	9.270
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.030
10	8.000	.430	1.810	0.000	7.050	0.000	0.000	0.000	.060
11	0.000	278.800	421.500	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	3.760	35.080	0.000	.980	0.000	0.000	0.000	25.500
13	0.000	0.000	804.810	0.000	0.000	0.000	0.000	0.000	3.970
14	44.070	73.980	25.290	41.190	38.210	0.000	0.000	0.000	103.920
15	0.000	0.000	0.000	0.000	617.700	0.000	4.100	5.600	600.130
16	195.340	543.580	203.720	87.930	471.870	0.000	0.000	31.210	7.960
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	1.820	10.900	9.690	4.240	4.240	7.340	21.110	4.540	8.990
19	450.630	657.690	585.490	229.580	604.500	445.400	5.820	19.230	1444.410

FINAL DEMAND	TOTAL OUTPUT
12843.000	30517.050
5840.000	6790.720
99.000	287.560
537.000	701.410
461.000	818.530
455.000	533.500
2667.000	2834.550
12518.000	13974.290
31.000	32.510
30.000	57.740
1691.000	2460.010
5314.000	5513.730
2626.000	3477.800
598.000	929.250
2453.000	4222.630
2260.000	4295.840
0.000	141.200
10.000	101.940
1171.000	8324.280

DIRECT COEFFICIENTS

SECTOR	1	2	3	4	5	6	7	8	9	10
1	.050849	.110943	0.000000	0.000000	.001051	0.000000	0.000000	.839270	.003999	.029789
2	.021697	.031154	0.000000	0.000000	.034562	0.000000	0.000000	0.000000	0.000000	0.000000
3	0.000000	.005107	0.000000	.162045	.002920	0.000000	0.000000	0.000000	.029529	0.000000
4	.001147	0.000000	.005042	.006900	.002688	.002699	.000427	.000117	.008920	.002598
5	.002574	0.000000	.012971	.004833	.000684	0.000000	0.000000	.000254	.091357	.003810
6	0.000000	0.000000	0.000000	0.000000	0.000000	.021237	.000303	.001690	.190095	0.000000
7	0.000000	0.000000	0.000000	.018948	0.000000	.000525	.018394	.000049	.002768	0.000000
8	.002055	0.000000	0.000000	0.000000	0.000000	.018182	.017435	.060020	0.000000	.011950
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.008313
10	0.000000	0.000000	0.000000	0.000000	.001185	.001856	.000794	.000383	.025531	0.000000
11	.001749	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.001098	0.000000	0.000000
12	0.000000	.019326	0.000000	0.000000	.003873	0.000000	0.000000	0.000000	0.000000	0.000000
13	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.003079	0.000000	0.000000
14	0.000000	0.000000	0.000000	0.000000	.004068	0.000000	0.000000	.000069	.005537	.002078
15	.017762	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.001538	0.000000
16	.000009	0.000000	.159862	.180622	.133410	.070159	.041936	.003468	.170102	.031521
17	.004627	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18	.000184	.000604	.005877	.003536	.001991	.001818	.000300	.000078	.001846	.010391
19	.006218	.105877	.077897	.211631	.204110	.224536	.032686	.086909	.196555	.529442

SECTOR	11	12	13	14	15	16	17	18	19
1	.507823	.373058	.004572	.201195	.023995	0.000000	0.000000	0.000000	.003320
2	0.000000	.001536	.009558	0.000000	0.000000	0.000000	0.000000	0.000000	.000846
3	0.000000	0.000000	0.000000	.008771	.006740	0.000000	0.000000	0.000000	.000031
4	.001691	.005657	.003908	.005230	.001786	.001457	.001487	0.000000	.005813
5	0.000000	.000742	.035163	.042055	.008462	0.000000	0.000000	0.000000	.007614
6	0.000000	0.000000	0.000000	0.000000	.008646	0.000000	0.000000	0.000000	0.000000
7	0.000000	.000094	.000561	0.000000	.015590	0.000000	.000992	.153031	.002046
8	0.000000	.004177	.000693	0.000000	.109015	0.000000	0.000000	0.000000	.001114
9	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	.000124
10	.003252	.000078	.000520	0.000000	.001670	0.000000	0.000000	0.000000	.000007
11	0.000000	.050565	.121197	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12	0.000000	.000682	.010087	0.000000	.000232	0.000000	0.000000	0.000000	.003063
13	0.000000	0.000000	.231414	0.000000	0.000000	0.000000	0.000000	0.000000	.000477
14	.017915	.013417	.007272	.044326	.009049	0.000000	0.000000	0.000000	.012484
15	0.000000	0.000000	0.000000	0.000000	.146283	0.000000	.029037	.054934	.072094
16	.079406	.098587	.058577	.094625	.111748	0.000000	0.000000	.306160	.000956
17	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18	.000740	.001977	.002786	.004563	.001004	.001709	.149504	.044536	.001080
19	.183182	.119282	.168351	.247059	.143157	.103682	.041218	.188640	.173518

DIRECT AND INDIRECT COEFFICIENTS

SECTOR	1	2	3	4	5	6	7	8	9	10
1	1.062928	.133157	.002690	.006723	.013943	.023792	.017925	.952460	.018623	.057267
2	.023933	1.035359	.000676	.000778	.036367	.000899	.000465	.021645	.004166	.002270
3	.000527	.005612	1.001133	.163937	.004128	.001009	.000179	.000709	.032236	.001948
4	.001415	.001192	.006133	1.010052	.004731	.004774	.000839	.002155	.012676	.007009
5	.003122	.001755	.014157	.009839	1.003514	.002810	.000518	.004290	.095725	.010940
6	.000221	.000139	.000103	.000259	.000224	1.021979	.000393	.002129	.194590	.002189
7	.000618	.000726	.001594	.021445	.001505	.002076	1.019013	.001075	.005115	.004372
8	.005140	.002298	.001466	.003914	.003247	.023259	.019558	1.064813	.002654	.020608
9	.000003	.000018	.000016	.000039	.000045	.000053	.000013	.000021	1.000263	.008399
10	.000053	.000036	.000039	.000079	.001237	.001958	.000826	.000487	.026080	1.000347
11	.001895	.001282	.000039	.000093	.000327	.000149	.000075	.003415	.000156	.000293
12	.000538	.020472	.000454	.001020	.005462	.000957	.000167	.000899	.001616	.002172
13	.000032	.000098	.000083	.000210	.000188	.000279	.000110	.004369	.000268	.000501
14	.000528	.002327	.001803	.004399	.008264	.004203	.000711	.002263	.011528	.011677
15	.023931	.014918	.011024	.026904	.024232	.026005	.004652	.031420	.034227	.058920
16	.004100	.005875	.166741	.216446	.140732	.077832	.043923	.009854	.211752	.048678
17	.004918	.000616	.000012	.000031	.000065	.000110	.000083	.004407	.000086	.000265
18	.001064	.001062	.006675	.005574	.002832	.002549	.000498	.001235	.003952	.011991
19	.018715	.142788	.124786	.312670	.281331	.300089	.050259	.134684	.376334	.674187

SECTOR	11	12	13	14	15	16	17	18	19
1	.548926	.435207	.109766	.231264	.159483	.002634	.008355	.017825	.025021
2	.012687	.011656	.017400	.007208	.004281	.000216	.000330	.000797	.002064
3	.001189	.001659	.001932	.010998	.008959	.000469	.000764	.001128	.002200
4	.004192	.007734	.008093	.008319	.004283	.002275	.002338	.002630	.007701
5	.004664	.004341	.049836	.048055	.013337	.001191	.001385	.003460	.011290
6	.000316	.000244	.000303	.000330	.010828	.000105	.000493	.000914	.000990
7	.001454	.001528	.002900	.002412	.019978	.000801	.026565	.165542	.004696
8	.005452	.008601	.005454	.005073	.140039	.001474	.006819	.014404	.013920
9	.000059	.000026	.000054	.000045	.000049	.000016	.000014	.000041	.000156
10	.003324	.000300	.001316	.000126	.002109	.000023	.000116	.000304	.000216
11	1.001041	.051430	.158660	.000511	.000581	.000037	.000051	.000128	.000358
12	.001061	1.001513	.014736	.001425	.001208	.000411	.000349	.001004	.003932
13	.000181	.000152	1.301327	.000241	.000721	.000087	.000093	.000250	.000828
14	.022484	.017763	.018134	1.051594	.014796	.001817	.001897	.004978	.017378
15	.033347	.025333	.031922	.035243	1.196564	.011163	.053200	.093995	.105740
16	.088092	.110839	.106035	.115672	.142381	1.002892	.056181	.340379	.019246
17	.002540	.002014	.000508	.001070	.000738	.000012	1.000039	.000082	.000116
18	.001950	.003095	.004924	.006090	.002188	.001979	.156794	1.047796	.001743
19	.257134	.189588	.347011	.355286	.257334	.130028	.105669	.310237	1.244605

	FINAL DEMANDS(1)	TOTAL OUTPUTS(1)	IMPORTS(1)	TOTAL PRODUCTION(1)	INCREASED PRODUCTION(1)
1	16865.000	42227.372	827.000	41400.372	11556.322
2	7669.000	8982.655	95.000	8887.655	2173.935
3	159.000	471.666	62.000	409.666	168.106
4	1022.000	1262.124	40.000	1222.124	553.714
5	878.000	1395.132	109.000	1286.132	558.602
6	866.000	991.069	0.000	991.069	457.569
7	4295.000	4558.251	1520.000	3038.251	1339.701
8	18142.000	20310.423	59.000	20251.423	6325.133
9	59.000	61.218	4.000	57.218	27.708
10	43.000	84.974	15.000	69.974	24.234
11	2394.000	3481.461	7.000	3474.461	1020.451
12	7524.000	7796.953	94.000	7702.953	2272.223
13	3718.000	4926.383	38.000	4888.383	1444.583
14	867.000	1348.989	39.000	1309.989	412.739
15	3951.000	6554.479	19.000	6535.479	2326.849
16	3640.000	6725.452	0.000	6725.452	2429.612
17	0.000	195.383	0.000	195.383	54.183
18	16.000	149.958	0.000	149.958	48.018
19	1697.000	12214.796	0.000	12214.796	3890.516

PROJECTED TRANSACTIONS TABLE(1)

SECTOR	1	2	3	4	5	6	7	8	9	10
1	2147.204	996.559	0.000	0.000	1.466	0.000	0.000	17045.925	.245	2.531
2	916.196	279.848	0.000	0.000	48.219	0.000	0.000	0.000	0.000	0.000
3	0.000	45.874	0.000	204.521	4.074	0.000	0.000	0.000	1.808	0.000
4	44.431	0.000	2.378	8.709	3.750	2.675	1.946	2.369	.546	.221
5	108.678	0.000	6.118	6.100	.954	0.000	0.000	5.160	5.593	.324
6	0.000	0.000	0.000	0.000	0.000	21.047	1.383	34.330	11.637	0.000
7	0.000	0.000	0.000	23.914	0.000	.520	83.847	.988	.169	0.000
8	86.760	0.000	0.000	0.000	0.000	18.019	79.472	1219.036	0.000	1.015
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.706
10	0.000	0.000	0.000	0.000	1.653	1.839	3.618	7.776	1.563	0.000
11	73.836	0.000	0.000	0.000	0.000	0.000	0.000	22.310	0.000	0.000
12	0.000	173.602	0.000	0.000	5.403	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	62.526	0.000	0.000
14	0.000	0.000	0.000	0.000	5.676	0.000	0.000	1.395	.339	.177
15	750.051	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.094	0.000
16	.360	0.000	75.402	227.967	186.124	69.533	191.155	70.432	10.413	2.678
17	195.383	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	7.749	5.423	2.772	4.463	2.778	1.802	1.367	1.584	.113	.883
19	262.563	951.055	36.741	267.104	284.760	222.531	148.991	1765.156	12.033	44.989

SECTOR	11	12	13	14	15	16	17	18	19
1	1767.966	2908.714	22.523	271.409	157.272	0.000	0.000	0.000	40.558
2	0.000	11.977	47.085	0.000	0.000	0.000	0.000	0.000	10.330
3	0.000	0.000	0.000	11.831	44.176	0.000	0.000	0.000	.382
4	5.887	44.106	19.251	7.055	11.704	9.800	.291	0.000	71.006
5	0.000	5.784	173.227	56.732	55.461	0.000	0.000	0.000	93.002
6	0.000	0.000	0.000	0.000	56.672	0.000	0.000	0.000	0.000
7	0.000	.735	2.762	0.000	102.183	0.000	.194	22.948	24.989
8	0.000	32.567	3.414	0.000	714.537	0.000	0.000	0.000	13.603
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.511
10	11.322	.608	2.564	0.000	10.943	0.000	0.000	0.000	.088
11	0.000	394.250	597.064	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	5.317	49.692	0.000	1.521	0.000	0.000	0.000	37.418
13	0.000	0.000	1140.032	0.000	0.000	0.000	0.000	0.000	5.825
14	62.369	104.615	35.824	59.795	59.311	0.000	0.000	0.000	152.489
15	0.000	0.000	0.000	0.000	958.810	0.000	5.673	8.238	880.613
16	276.449	768.675	288.574	127.648	732.449	0.000	0.000	45.911	11.680
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	2.576	15.414	13.726	6.155	6.581	11.491	29.211	6.679	13.192
19	637.742	930.038	829.360	333.281	938.321	697.306	8.053	28.288	2119.483

	FINAL DEMANDS(2)	TOTAL OUTPUTS(2)	IMPORTS(2)	TOTAL PRODUCTION(2)	INCREASED PRODUCTION(2)
1	22148.000	58590.293	1016.000	57574.293	16173.921
2	10071.000	11895.464	116.000	11779.464	2891.809
3	257.000	787.548	82.000	705.548	295.882
4	1946.000	2299.826	47.000	2252.826	1030.702
5	1670.000	2422.394	131.000	2291.394	1005.262
6	1649.000	1850.737	0.000	1850.737	859.668
7	6917.000	7333.862	2034.000	5299.862	2261.612
8	26294.000	29535.330	72.000	29463.330	9211.907
9	112.000	115.292	5.000	110.292	53.074
10	63.000	127.091	18.000	109.091	39.117
11	3390.000	4928.440	8.000	4920.440	1445.979
12	10653.000	11027.913	106.000	10921.913	3218.960
13	5265.000	6979.749	44.000	6935.749	2047.366
14	1256.000	1960.718	48.000	1912.718	602.729
15	6362.000	10220.469	25.000	10195.469	3659.990
16	5862.000	10591.042	0.000	10591.042	3865.589
17	0.000	271.093	0.000	271.093	75.710
18	26.000	223.094	0.000	223.094	73.135
19	2460.000	18065.170	0.000	18065.170	5850.375

PROJECTED TRANSACTIONS TABLE(2)

SECTOR	1	2	3	4	5	6	7	8	9	10
1	2979.236	1319.714	0.000	0.000	2.545	0.000	0.000	24788.112	.461	3.786
2	1271.217	370.595	0.000	0.000	83.723	0.000	0.000	0.000	0.000	0.000
3	0.000	60.750	0.000	372.675	7.073	0.000	0.000	0.000	3.404	0.000
4	67.197	0.000	3.971	15.870	6.511	4.995	3.131	3.445	1.028	.330
5	150.791	0.000	10.215	11.115	1.657	0.000	0.000	7.503	10.533	.484
6	0.000	0.000	0.000	0.000	0.000	39.304	2.225	49.922	21.916	0.000
7	0.000	0.000	0.000	43.576	0.000	.971	134.902	1.437	.319	0.000
8	120.379	0.000	0.000	0.000	0.000	33.650	127.865	1772.717	0.000	1.519
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.057
10	0.000	0.000	0.000	0.000	2.871	3.434	5.821	11.307	2.943	0.000
11	102.447	0.000	0.000	0.000	0.000	0.000	0.000	32.443	0.000	0.000
12	0.000	229.896	0.000	0.000	9.381	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	90.925	0.000	0.000
14	0.000	0.000	0.000	0.000	9.855	0.000	0.000	2.029	.638	.264
15	1040.693	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.177	0.000
16	.499	0.000	125.899	415.399	323.171	129.846	307.554	102.423	19.611	4.006
17	271.293	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	10.752	7.182	4.628	8.132	4.824	3.365	2.199	2.304	.213	1.321
19	364.305	1259.454	61.347	486.714	494.434	415.557	239.714	2566.883	22.661	67.288

SECTOR	11	12	13	14	15	16	17	18	19.
1	2502.776	4114.049	31.910	394.486	245.235	0.000	0.000	0.000	59.984
2	0.000	16.941	66.711	0.000	0.000	0.000	0.000	0.000	15.278
3	0.000	0.000	0.000	17.197	68.885	0.000	0.000	0.000	.564
4	8.334	62.383	27.274	10.255	18.250	15.434	.403	0.000	105.015
5	0.000	8.180	245.429	82.459	86.481	0.000	0.000	0.000	137.546
6	0.000	0.000	0.000	0.000	88.369	0.000	0.000	0.000	0.000
7	0.000	1.040	3.914	0.000	159.335	0.000	.269	34.140	36.958
8	0.000	46.062	4.837	0.000	1114.184	0.000	0.000	0.000	20.118
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.235
10	16.027	.860	3.633	0.000	17.064	0.000	0.000	0.000	.130
11	0.000	557.623	845.927	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	7.520	70.404	0.000	2.372	0.000	0.000	0.000	55.340
13	0.000	0.000	1615.208	0.000	0.000	0.000	0.000	0.000	8.616
14	88.291	147.966	50.756	86.911	92.484	0.000	0.000	0.000	225.525
15	0.000	0.000	0.000	0.000	1495.083	0.000	7.872	12.255	1302.389
16	391.349	1087.205	408.855	185.532	1142.116	0.000	0.000	68.302	17.275
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	3.646	21.801	19.447	8.946	10.263	18.096	40.530	9.936	19.510
19	902.802	1315.434	1175.045	484.414	1463.134	1098.097	11.174	42.084	3134.627

	FINAL DEMANDS(3)	TOTAL OUTPUTS(3)	IMPORTS(3)	TOTAL PRODUCTION(3)	INCREASED PRODUCTION(3)
1	29084.000	81512.115	1248.000	80264.115	22689.822
2	13225.000	15774.243	143.000	15631.243	3851.779
3	414.000	1332.884	110.000	1222.884	517.336
4	3704.000	4230.687	57.000	4173.687	1920.861
5	3180.000	4282.139	157.000	4125.139	1833.745
6	3138.000	3467.903	0.000	3467.903	1617.166
7	11140.000	11805.237	2122.000	9683.237	4383.374
8	38107.000	42972.157	89.000	42883.157	13419.826
9	214.000	218.914	6.000	212.914	102.622
10	91.000	189.897	22.000	167.897	58.805
11	4800.000	6976.943	9.000	6967.943	2047.503
12	15084.000	15602.099	120.000	15482.099	4560.186
13	7454.000	9887.170	49.000	9838.170	2902.422
14	1820.000	2856.180	59.000	2797.180	884.462
15	10247.000	16009.756	34.000	15975.756	5780.286
16	9440.000	16778.853	0.000	16778.853	6187.812
17	0.000	377.150	0.000	377.150	106.057
18	42.000	335.127	0.000	335.127	112.033
19	3565.000	26954.622	0.000	26954.622	8889.452

PROJECTED TRANSACTIONS TABLE(3)

SECTOR	1	2	3	4	5	6	7	8	9	10
1	4144.779	1750.035	0.000	0.000	4.499	0.000	0.000	36065.235	.875	5.657
2	1768.546	491.435	0.000	0.000	147.999	0.000	0.000	0.000	0.000	0.000
3	0.000	80.559	0.000	685.562	12.503	0.000	0.000	0.000	6.464	0.000
4	93.486	0.000	6.721	29.193	11.509	9.360	5.039	5.012	1.953	.493
5	209.783	0.000	17.289	20.447	2.930	0.000	0.000	10.917	19.999	.724
6	0.000	0.000	0.000	0.000	0.000	73.648	3.582	72.634	41.615	0.000
7	0.000	0.000	0.000	80.161	0.000	1.820	217.151	2.091	.606	0.000
8	167.474	0.000	0.000	0.000	0.000	63.053	205.823	2579.198	0.000	2.269
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.579
10	0.000	0.000	0.000	0.000	5.075	6.435	9.371	16.452	5.589	0.000
11	142.526	0.000	0.000	0.000	0.000	0.000	0.000	47.203	0.000	0.000
12	0.000	304.859	0.000	0.000	16.584	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	132.290	0.000	0.000
14	0.000	0.000	0.000	0.000	17.421	0.000	0.000	2.952	1.212	.395
15	1447.835	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.337	0.000
16	.694	0.000	213.078	764.155	571.280	243.306	495.066	149.019	37.238	5.986
17	377.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	14.958	9.524	7.833	14.959	8.527	6.305	3.540	3.352	.404	1.973
19	506.829	1670.127	103.827	895.344	874.027	778.669	385.866	3734.662	43.029	100.539

PROJECTED TRANSACTIONS TABLE (3) CONTINUED

SECTOR	11	12	13	14	15	16	17	18	19
1	3543.053	5820.485	45.203	574.648	384.146	0.000	0.000	0.000	89.500
2	0.000	23.967	94.499	0.000	0.000	0.000	0.000	0.000	22.796
3	0.000	0.000	0.000	25.050	107.904	0.000	0.000	0.000	.842
4	11.798	88.258	38.636	14.938	28.587	24.451	.561	0.000	156.690
5	0.000	11.573	347.663	120.118	135.467	0.000	0.000	0.000	205.229
6	0.000	0.000	0.000	0.000	138.425	0.000	0.000	0.000	0.000
7	0.000	1.471	5.544	0.000	249.589	0.000	.374	51.285	55.144
8	0.000	65.168	6.851	0.000	1745.304	0.000	0.000	0.000	30.017
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.335
10	22.689	1.217	5.146	0.000	26.729	0.000	0.000	0.000	.194
11	0.000	788.915	1198.298	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	10.640	99.730	0.000	3.716	0.000	0.000	0.000	82.571
13	0.000	0.000	2288.025	0.000	0.000	0.000	0.000	0.000	12.855
14	124.989	209.340	71.898	126.603	144.870	0.000	0.000	0.000	336.500
15	0.000	0.000	0.000	0.000	2341.959	0.000	10.951	18.410	1943.264
16	554.012	1538.158	579.163	270.265	1789.056	0.000	0.000	102.603	25.775
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	5.162	30.844	27.548	13.032	16.076	28.669	56.386	14.925	29.110
19	1278.052	1861.053	1664.512	705.646	2291.912	1739.660	15.545	63.218	4677.104

	FINAL DEMANDS(4)	TOTAL OUTPUTS(4)	IMPORTS(4)	TOTAL PRODUCTION(4)	INCREASED PRODUCTION(4)
1	38193.000	113721.260	1533.000	112188.260	31924.145
2	17367.000	20954.773	175.000	20779.773	5148.530
3	666.000	2286.182	148.000	2138.182	915.298
4	7050.000	7843.223	68.000	7775.223	3601.537
5	6052.000	7679.087	188.000	7491.087	3365.948
6	5973.000	6519.443	0.000	6519.443	3051.540
7	17942.000	19011.827	3643.000	15368.827	5685.591
8	55229.000	62563.087	109.000	62454.087	19570.930
9	407.000	414.407	7.000	407.407	194.493
10	132.000	286.285	27.000	259.285	91.389
11	6796.000	9877.676	10.000	9867.676	2899.733
12	21358.000	22079.373	136.000	21943.373	6461.274
13	10554.000	14007.504	58.000	13949.504	4111.334
14	2638.000	4171.446	73.000	4098.446	1301.266
15	16502.000	25178.061	45.000	25133.061	9157.305
16	15204.000	26747.123	0.000	26747.123	9968.269
17	0.000	526.179	0.000	526.179	149.029
18	67.000	508.339	0.000	508.339	173.212
19	5166.000	40629.654	0.000	40629.654	13675.031

PROJECTED TRANSACTIONS TABLE(4)

SECTOR	1	2	3	4	5	6	7	8	9	10
1	5782.570	2324.777	0.000	0.000	8.068	0.000	0.000	52507.311	1.657	8.528
2	2467.379	652.831	0.000	0.000	265.404	0.000	0.000	0.000	0.000	0.000
3	0.000	107.015	0.000	1270.955	22.422	0.000	0.000	0.000	12.237	0.000
4	130.427	0.000	11.528	54.121	20.639	17.597	8.116	7.298	3.697	.744
5	292.678	0.000	29.655	37.907	5.254	0.000	0.000	15.893	37.859	1.091
6	0.000	0.000	0.000	0.000	0.000	138.454	5.768	105.747	78.777	0.000
7	0.000	0.000	0.000	148.610	0.000	3.422	349.712	3.044	1.147	0.000
8	233.650	0.000	0.000	0.000	0.000	118.535	331.469	3755.050	0.000	3.421
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.380
10	0.000	0.000	0.000	0.000	9.100	12.098	15.091	23.952	10.580	0.000
11	198.845	0.000	0.000	0.000	0.000	0.000	0.000	68.722	0.000	0.000
12	0.000	404.980	0.000	0.000	29.740	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	192.601	0.000	0.000
14	0.000	0.000	0.000	0.000	31.241	0.000	0.000	4.298	2.294	.595
15	2019.540	0.000	0.000	0.000	0.000	0.000	0.000	0.000	.637	0.000
16	.969	0.000	365.474	1416.658	1024.466	457.400	797.282	216.956	70.491	9.024
17	526.179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	21.868	12.652	13.436	27.732	15.292	11.854	5.701	4.880	.765	2.975
19	707.100	2218.625	178.086	1659.868	1567.377	1463.850	621.420	5437.288	81.454	151.572

SECTOR	11	12	13	14	15	16	17	18	19.
1	5016.112	8236.882	64.040	839.272	604.136	0.000	0.000	0.000	134.907
2	0.000	33.918	133.880	0.000	0.000	0.000	0.000	0.000	34.361
3	0.000	0.000	0.000	36.586	169.697	0.000	0.000	0.000	1.269
4	16.704	124.898	54.736	21.817	44.958	38.977	.783	0.000	236.185
5	0.000	16.378	492.546	175.432	213.045	0.000	0.000	0.000	309.349
6	0.000	0.000	0.000	0.000	217.696	0.000	0.000	0.000	0.000
7	0.000	2.082	7.854	0.000	392.521	0.000	.522	77.792	83.121
8	0.000	92.222	9.707	0.000	2744.786	0.000	0.000	0.000	45.246
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.027
10	32.122	1.722	7.290	0.000	42.037	0.000	0.000	0.000	.293
11	0.000	1116.436	1697.672	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	15.057	141.291	0.000	5.843	0.000	0.000	0.000	124.462
13	0.000	0.000	3241.526	0.000	0.000	0.000	0.000	0.000	19.377
14	176.954	296.248	101.860	184.904	227.833	0.000	0.000	0.000	507.219
15	0.000	0.000	0.000	0.000	3683.128	0.000	15.279	27.925	2929.151
16	784.348	2176.731	820.521	394.722	2813.595	0.000	0.000	155.633	38.852
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	7.308	43.648	39.028	19.034	25.282	45.701	78.666	22.639	43.879
19	1809.414	2633.677	2358.173	1030.595	3604.421	2773.187	21.688	95.893	7049.964

```
      PROGRAM RIP3JC(INPUT,OUTPUT)
      COMMON II,N,M0,A(133,90),C(90),B(133),K0(6),XL(90),D(90),
     1  JH(90),XX(90),Y(90),OBJ,E(133,90),NOP
      COMMON BS(133),S(90),SB(90),NS(90),SMAX(90),SMAXB(90),
     1  T(90),CS(90),PE(90),ITEMP(4),JTEMP(4),ATEMP(4)
      COMMON MS(90),NF(90),ZBAR,IR,LPSEQ
      REAL MAXT
      INTEGER BCIB,BLANK
      INTEGER S,SMAX,SC,T,SB,SMAXB
      DATA NLIM,MLIM/90,133/
      DATA BCIB/6HB     /
      DATA BLANK/6H      /
  100 DO 110 I=1,NLIM
      D(I) = 0.
      JH(I) = 0
      PE(I) = 0.
      XL(I) = 0
      XX(I) = 0.
      Y(I) = 0.
      MS(I) = 0
      DO 105 J = 1,NLIM
  105 E(I,J) = 0.
      C(I)=0.0
      BS(I)=0.0
      S(I)=0
      SB(I)=BLANK
      NS(I)=0
      NF(I)=0
      SMAX(I)=0
      SMAXB(I)=BLANK
      T(I)=0
      DO 110 J=1,MLIM
      A(J,I)=0.0
  110 CONTINUE
      DO 115 J = 1,MLIM
  115 B(J) = 0.
      IR = 0
      LPSEQ = 0
      II=0
      NCON=0
      NRED=0
      NAUG=0
      NOPT=0
      NID=0
      NAP=0
      NLPF=0
      NSIMP=0
      NPATH=0
      NENUM=0
      NTCE=0
      NCID2=0
      IPOST=1
      IFPST=1
      IINS=5
C  READ A NEW SET OF DATA
C  PARAMETER CARD FIRST
C  ≠S≠ CARD SECOND
C  ≠C≠,≠B≠,≠A≠ MATRICES FOLLOW ≠S≠
C  MINIMIZE SUM C(J)*X(J)
C  CONSTRAINTS ARE B(I)+SUM A(I,J)*X(J) GE ZERO
      READ 9000,M,N,L,SC,KENUM,ZBAR,ISCMAX,ISCFR,MAXC,MAXQ,
     *             NOP,ZKBAR,ITB,H1,H2
      IF (M .LE. 0) STOP
      MAXT = MAXQ
 9000 FORMAT (4I3,I5,E6.0,3I3,I5,I3,E6.0,I3,2A6)
      PRINT 9002
 9002 FORMAT(*1PARAMETERS*/*  M  N   L SC KENUM     ZBAR   ISCMAX ISCFR
     1MAXC MAXT NOP   ZKBAR      ITB   TITLE*)
      PRINT 9001,M,N,L,SC,KENUM,ZBAR,ISCMAX,ISCFR,MAXC,MAXQ,
     *             NOP,ZKBAR,ITB,H1,H2
 9001 FORMAT (4I3,I5,1X,E11.4,3I6,I5,I4,E11.4,1X,I3,1X,2A6)
      IF (MAXT.EQ.0) MAXT=999999
      M0=M
      M1=M0+1
      JSCFR=ISCFR
      ZKBAR=ZKBAR+.99999
      PRINT 9010,M,N
 9010 FORMAT(*0DIMENSIONS..  M = *,I3,*,  N = *,I3)
      PRINT 9992
 9991 FORMAT (1H )
 9992 FORMAT (1H0)
 9993 FORMAT (1H1)
      L1=L
      IF (L.LE.0) L1=0
      READ 9100,((S(K),SB(K)),K=1,L1)
```

```
 9100 FORMAT (14(I4,A1))
      IF (L.GE.0) GO TO 130
      L=0
      IFRST=0
  130 CONTINUE
      READ 9200,(C(J),J=1,N)
C*******************************
 9200 FORMAT(E10.3,5E12.3)
      IF (MAXC.EQ.0) GO TO 141
      DO 140 J=1,N
  140 C(J)=-C(J)
  141 CONTINUE
      READ 9200,(B(I),I=1,M)
  200 READ 9400,((ITEMP(K),JTEMP(K),ATEMP(K)),K=1,4)
 9400 FORMAT (4(2I3,E10.3,1X))
      END=0.0
      DO 250 K=1,4
      KI=ITEMP(K)
      KJ=JTEMP(K)
      IF (KI.EQ.0) GO TO 250
      IF (KJ.EQ.0) GO TO 250
C*******************************
      IF (MAXC.NE.0) ATEMP(K)=-ATEMP(K)
      A(KI,KJ)=ATEMP(K)
      END=1.0
  250 CONTINUE
      IF (END.NE.0.0) GO TO 200
      PRINT 9020
 9020 FORMAT(*0INITIAL SOLUTION*)
      PRINT 9500,((S(K),SB(K)),K=1,L)
 9500 FORMAT (14(3X,I4,A1))
      PRINT 9030
      IF (MAXC .GT. 0) PRINT 9040
 9030 FORMAT(*0COST COEFFICIENTS*)
 9040 FORMAT(*+*,24X,*--SIGNS CHANGED*)
      PRINT 9600,(C(J),J=1,N)
      PRINT 9050
 9050 FORMAT(*0CONSTRAINT CONSTANTS*)
      PRINT 9600,(B(I),I=1,M)
      PRINT 9060
 9060 FORMAT(*0CONSTRANT MATRIX, BY ROWS*)
      IF (MAXC .GT. 0) PRINT 9040
      DO 251 I=1,M
      PRINT 9600,(A(I,J),J=1,N)
      PRINT 9991
  251 CONTINUE
      PRINT 9992
C  ALL DATA READ FOR THIS RUN
C  PERFORM CHANGE OF VARIABLES NOW IF NECESSARY
      DO 255 J=1,N
      CS(J)=C(J)
      IF (C(J).GE.0.0) GO TO 255
      C(J)=-C(J)
      DO 253 I=1,M
      B(I)=B(I)+A(I,J)
  253 A(I,J)=-A(I,J)
  255 CONTINUE
 9600 FORMAT(1X,10E12.5)
      IF (ZBAR.GT.0.0) GO TO 300
      ZBAR=0.0
      DO 275 J=1,N
  275 ZBAR=ZBAR+C(J)
  300 ZS=0.0
      DO 325 I=1,M
  325 BS(I)=B(I)
      DO 330 J=1,N
  330 NS(J)=J
      IF (L.EQ.0) GO TO 400
      DO 375 K=1,L
      J1=S(K)
      K1=IABS(J1)
      NS(K1)=0
      IF (J1.LE.0) GO TO 375
      ZS=ZS+C(J1)
      DO 350 I=1,M
  350 BS(I)=BS(I)+A(I,J1)
  375 CONTINUE
  400 CONTINUE
      IF (M0+ISCMAX.GT.MLIM) ISCMAX = MLIM - M0
      I1=M0+ISCMAX
      CALL SECOND(T0)
      T1 = T0
      T2 = T0
      T3 = T0
C  INITIALIZATION COMPLETE NOW. START FIRST ITERATION
      GO TO 1910
C  PREPARE TO COMPUTE SURROGATE CONSTRAINT
 1000 CONTINUE
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```
      IF (SC.EQ.0) GO TO 2400
      JSCFR=JSCFR+1
      IF (ISCFR.GT.JSCFR) GO TO 2400
      ML=N-L
      IF (ML.LE.1) GO TO 2400
      JSCFR=0
 1050 DO 1060 J=1,N
 1060   MS(J)=0
      NSIMP=NSIMP+1
      IF(L.EQ.0) GO TO 1076
      DO 1075 I=1,L
        J=IABS(S(I))
 1075   MS(J) =-S(I)
      IF (NOP.NE.0) GO TO 1076
      PRINT 9070
 9070 FORMAT(*0CURRENT PARTIAL SOLUTION*)
      PRINT 3600,((S(K),SB(K)),K=1,L)
C  SOLVE THE IMBEDDED LINEAR PROGRAM
 1076 CALL SIMPLE
      IF (NOP.NE.0) GO TO 1077
      PRINT 9080, OBJ,ZBAR
 9080 FORMAT(* OBJ,ZBAR*2E15.6)
 1077 CONTINUE
      II=II+IPOST
C  KO(1) EQ 0 MEANS OBJ LESS THAN ZBAR, EQ 2 MEANS INFINITY, EQ 4 MEANS
C  TROUBLE, EQ 6 MEANS OBJ GE ZBAR
      IF (KO(1).EQ.2) GO TO 3400
      IF (KO(1).EQ.4) GO TO 100
      IF (KO(1).EQ.6) GO TO 1500
      VLPS=-OBJ
      IF (VLPS.LE. (-ZBAR))GO TO 1499
      DO 1350 I=1,N
      IF (D(I).NE.AINT(D(I)).AND.NS(I).NE.0)  GO TO 1500
 1350 CONTINUE
      DO 1450 J=1,N
      IF (NS(J).EQ.0) GO TO 1450
      I=J
      L=L+1
      NS(J)=0
      SB(L)=BCIB
      IF (D(I).NE.0.0) GO TO 1400
      S(L)=-J
      GO TO 1450
 1400 S(L)=J
      ZS=ZS+C(J)
      DO 1425 I1=1,M
 1425 BS(I1)=BS(I1)+A(I1,J)
C  NATURAL DUAL INTEGER SOLUTION FOUND
 1450 CONTINUE
      NID=NID+1
      GO TO 2320
 1499 KO(1)=6
C  COMPUTE NEW SURROGATE CONSTRAINT
 1500 IF (ISCMAX.LE.0) GO TO 1599
      BMP1=ZBAR
      DO 1505 I=1,M0
 1505 BMP1=BMP1+XL(I)*B(I)
      IF (ABS(BMP1-B(M)).LE.0.0005) GO TO 1599
      IF (M-M0.LT.ISCMAX) GO TO 1520
      DO 1510 I=M1,M
      B(I)=B(I+1)
      BS(I)=BS(I+1)
      DO 1510 J=1,N
 1510 A(I,J)=A(I+1,J)
      M=M-1
 1520 B(M+1)=BMP1
      DO 1550 J=1,N
      ZJH =XX(J)
      IF (JH(J).GE.(-N)) ZJH=-ZJH
      IF (JH(J).GT.0) ZJH=0.
 1550 A(M+1,J)=ZJH
      M=M+1
      BS(M)=B(M)
      DO 1575 K=1,L
      K1=S(K)
      IF (K1.LE.0) GO TO 1575
      BS(M)=BS(M)+A(M,K1)
 1575 CONTINUE
      IF (NOP.NE.0) GO TO 1599
      PRINT 1598,M
      PRINT 9600,(A(M,J),J=1,N),B(M),BS(M)
 1598 FORMAT (21H0SURROGATE CONSTRAINT,2X,I4)
 1599 IF (KO(1).EQ.6) GO TO 3400
C  CHECK THE ROUNDED DUAL SOLUTION FOR FEASIBILITY
 1900 CONTINUE
      TU=.5
  900 F=ZS
      F1=BS(M)
  905 DO 910 J=1,N
      IF (NS(J).EQ.0) GO TO 910
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```
      IF (D(J).LT.TD) GO TO 910
      F=F+C(J)
      F1=F1+A(M,J)
  910 CONTINUE
      IF (F.GE.ZBAR) GO TO 2400
      IF (F1.GE.0.0) GO TO 920
  915 GO TO 2400
  920 DO 930 I=1,M0
      F2=BS(I)
      DO 925 J=1,N
      IF (NS(J).EQ.0) GO TO 925
      IF (D(J).LT.TD) GO TO 925
      F2=F2+A(I,J)
  925 CONTINUE
      IF (F2.LT.0.0) GO TO 915
  930 CONTINUE
C  BOUNDED DUAL SOLUTION FEASIBLE
  931 NCID2=NCID2+1
  932 NOPT=NOPT+1
      CALL SECOND(T3)
      IF (M.EQ.M0) GO TO 940
      DO 935 I=M1,M
      B(I)=B(I)+F-ZKBAR-ZBAR
  935 BS(I)=BS(I)+F-ZKBAR-ZBAR
  940 ZBAR=F-ZKBAR
      DO 945 J=1,L
      SMAXB(J)=SB(J)
  945 SMAX(J)=S(J)
      K=L
      DO 950 J=1,N
      IF (NS(J).EQ.0) GO TO 950
      K=K+1
      SMAXB(K)=BLANK
      SMAX(K)=J
      IF (D(J).LT.TD) SMAX(K)=-J
  950 CONTINUE
      IF (NOP.NE.0) GO TO 960
     /PRINT 3310,F
      PRINT 3600,((SMAX(J),SMAXB(J)),J=1,N)
  960 CONTINUE
      NOBJ=OBJ
      ZOBJ=NOBJ
      IF (OBJ.NE.ZOBJ) ZOBJ=ZOBJ+1.0
      IF (F.EQ.ZOBJ) GO TO 3500
      GO TO 2400
C  BEGINNING OF AN ITERATION. MAKE CHEAP ATTEMPT TO FATHOM
 1910 IJK=0
 1920 CONTINUE
      IF (ZS.GE.ZBAR) GO TO 3100
      DO 1950 I1=1,M0
      IF (BS(I1).LT.0.0) GO TO 1980
 1950 CONTINUE
      GO TO 2320
C  SEE IF ANY VARIABLES MUST BE 0
 1980 CONTINUE
      DO 2000 J=1,N
      IF (NS(J).EQ.0) GO TO 2000
      IF (ZS+C(J).LT.ZBAR) GO TO 2000
      NS(J)=0
      L=L+1
      SB(L)=BCIB
      S(L)=-J
 2000 CONTINUE
      KINS=0
      IF (IJK.EQ.1) GO TO 2300
      IF (IJK.EQ.2) GO TO 1000
      IJK=1
      IF (M.LT.M1) GO TO 2025
      MSC=0
      I1=M1
      I2=M
      GO TO 2050
 2025 MSC=1
      I1=1
      I2=M0
C  PERFORM BINARY FEASIBILITY TEST
 2050 DO 2225 I=I1,I2
      Q=BS(I)
      DO 2100 J=1,N
      IF (NS(J).EQ.0) GO TO 2100
      IF (A(I,J).GT.0.0) Q=Q+A(I,J)
 2100 CONTINUE
 2110 IF (Q.LT.0.0) GO TO 3000
C  SEE IF ANY FREE VARIABLE MUST BE 0 OR 1
      DO 2200 J1 = 1,N
      IF (A(I,J1) .EQ. 0.0) GO TO 2200
      IF (NS(J1).EQ.0) GO TO 2200
 2120 IF (Q.GE.ABS(A(I,J1))) GO TO 2200
      NS(J1)=0
      L=L+1
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```
      SB(L)=BCIB
      IF (A(I,J1).GT.0.0) GO TO 2150
      S(L)=-J1
      GO TO 2200
 2150 S(L)=J1
      ZS=ZS+C(J1)
      DO 2175 I9=1,M
 2175 BS(I9)=BS(I9)+A(I9,J1)
      KINS=KINS+1
 2200 CONTINUE
 2300 CONTINUE
      IF(KINS.GE.IINS) GO TO 1920
      IF (KINS.GE.IINS) GO TO 1920
 2220 CONTINUE
      IF (MSC.EQ.0) GO TO 2025
      IF (KINS.EQ.0) GO TO 1000
      IJK=2
      GO TO 1920
C  A BETTER FEASIBLE SOLUTION HAS BEEN FOUND
 2320 CONTINUE
      IF (M.EQ.M0) GO TO 2340
C  REVISE B(I) AND BS(I) USING NEW ZS
      DO 2325 I=M1,M
      B(I)=B(I)+ZS-ZKBAR-ZBAR
 2325 BS(I)=BS(I)+ZS-ZKBAR-ZBAR
 2340 ZBAR=ZS-ZKBAR
      DO 2350 J=1,N
 2350 SMAX(J)=S(J)
      GO TO 3300
C  AUGMENTATION STEP
 2400 K1=0
      IF (SC.EQ.0) GO TO 2415
      IF (IFRST.NE.0) GO TO 2415
      IFRST=1
      DO 2410 J=1,N
      IF (NS(J).EQ.0) GO TO 2410
      J1=0
      IF (D(J).EQ.1.0) J1=J
      IF (D(J).EQ.0.0) J1=-J
      IF (J1.EQ.0) GO TO 2410
      L=L+1
      NS(J)=0
      S(L)=J1
      IF (J1.LT.0) GO TO 2410
      ZS=ZS+C(J)
      DO 2405 I=1,M
 2405 BS(I)=BS(I)+A(I,J)
 2410 CONTINUE
 2415 CONTINUE
      IF (ITB.EQ.0) GO TO 2425
      IF (JSCFR.NE.0) GO TO 2425
      DO 2420 J=1,N
      IF (NS(J).EQ.0) GO TO 2420
      IF (D(J).EQ.AINT(D(J))) GO TO 2420
      K1=K1+1
      T(K1)=J
 2420 CONTINUE
      GO TO 2505
 2425 CONTINUE
      DO 2500 J=1,N
      IF (NS(J).EQ.0) GO TO 2500
      K1=K1+1
      T(K1)=J
      GO TO 2500
 2450 CONTINUE
 2500 CONTINUE
 2505 CONTINUE
      IF (K1.EQ.0) GO TO 3200
      NAP=NAP+1
      P=-1.0E10
      DO 2575 K=1,K1
      J=T(K)
      P1=0.0
      DO 2550 I=1,M
      P2=BS(I)+A(I,J)
      IF (P2.GE.0.0) GO TO 2550
      P1=P1+P2
 2550 CONTINUE
      IF (P1.LE.P) GO TO 2575
      P=P1
      J1=J
 2575 CONTINUE
      NS(J1)=0
      L=L+1
      S(L)=J1
      ZS=ZS+C(J1)
      DO 2600 I=1,M
 2600 BS(I)=BS(I)+A(I,J1)
      GO TO 1910
C  FATHOMED DUE TO BINARY INFEASIBLE CONSTRAINT
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 3000 NCON=NCON+1
      GO TO 3500
 3100 NRED=NRED+1
      GO TO 3500
C  FATHOMED DUE TO LACK OF FREE VARIABLES
 3200 NAUG=NAUG+1
      GO TO 3500
 3300 NOPT=NOPT+1
      CALL SECOND(T3)
      IF (NOP.NE.0) GO TO 3500
      PRINT 3310,ZS
      PRINT 3600,((S(K),SB(K)),K=1,L)
 3310 FORMAT (23H0 BETTER SOLUTION FOUND,5X,2HZ=,1PE15.8)
      GO TO 3500
 3400 NLPF=NLPF+1
      GO TO 3500
C  BACKTRACK STEP
 3500 CONTINUE
      NENUM=NENUM+1
      IF (NENUM.LT.KENUM) GO TO 3530
      NENUM=0
 3505 CONTINUE
      ENUM=0.0
      DO 3510 K=1,N
 3510 IF (SB(K).EQ.BCIB) ENUM=ENUM+.5**K
      CALL SECOND(T2)
      ELT1 = T2 - T0
      ELT2 = T2 - T1
      T1 = T2
      IF (ELT1    .LT.MAXT) GO TO 3515
      MAXT=-1
      GO TO 3517
 3515 CONTINUE
      IF (NOP.NE.0) GO TO 3700
 3517 CONTINUE
      PRINT 3520,ENUM,ELT1,ELT2,L
 3520 FORMAT (1H0,F10.5,38H OF THE SOLUTIONS HAVE BEEN ENUMERATED,5X,
     *          15HTIME IN SECONDS,2X,5HTOTAL,F8.3,2X,7HELAPSED,F8.3,
     *          5X,2HL=,I3)
 3530 CONTINUE
      IF (MAXT .GE. 0.) GO TO 3700
      PRINT 9090
 9090 FORMAT(*0FINAL PARTIAL SOLUTION*)
      PRINT 3600,((S(K), SB(K)),K=1,L)
 3600 FORMAT (15(2X,I4,A1))
      GO TO 3738
 3700 NFATH=NFATH+1
 3710 IF (L .EQ. 0) GO TO 3738
      IF (SB(L) .EQ. BLANK) GO TO 3900
      J=IABS(S(L))
      NS(J)=J
      IF (S(L).LT.0) GO TO 3735
      ZS=ZS-C(J)
      DO 3725 I=1,M
 3725 BS(I)=BS(I)-A(I,J)
 3735 SB(L)=BLANK
      S(L)=0
      L=L-1
      IF (L.GT.0) GO TO 3710
C  FINISHED NOW. PREPARE AND GIVE FINAL OUTPUT.
 3738 CONTINUE
      PRINT 3739,H1,H2
 3739 FORMAT (1H1,5X,2A6)
      DO 3740 J=1,N
 3740 S(J)=0
      DO 3742 J=1,N
      K=IABS(SMAX(J))
      IF (K.EQ.0) GO TO 3744
 3742 S(K)=1
 3744 DO 3746 K=1,N
      IF (S(K).NE.0) GO TO 3746
      SMAX(J)=-K
      J=J+1
 3746 CONTINUE
      CALL SECOND(T2)
      ELT1 = T2 - T0
      IF (MAXT.LT.0) GO TO 3752
      PRINT 3750,ELT1
 3750 FORMAT (30H0IMPLICIT ENUMERATION COMPLETE,5X,11HTOTAL TIME=,F8.3)
      GO TO 3758
 3752 PRINT 3755,ELT1
 3755 FORMAT (14H0TIME EXCEEDED,5X,11HTOTAL TIME=,F8.3)
 3758 CONTINUE
      ZBAR=0.0
      DO 3835 J=1,N
      K=IABS(SMAX(J))
      IF (CS(K).LT.0.0) SMAX(J)=-SMAX(J)
      IF (SMAX(J).GT.0) ZBAR=ZBAR+CS(K)
 3835 CONTINUE
      PRINT 3840,ZBAR
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 3840 FORMAT(*0SOLUTION BEFORE VARIABLE CHANGE Y(J) = 1 - X(J) IF C(J) I
     1S NEGATIVE..*/* LEAST Z = *,1PE17.8)
 3800 DO 3810 K=1,N
 3810 T(K)=0
      DO 3820 K=1,N
      K1=IABS(SMAX(K))
 3820 IF (SMAX(K).GT.0) T(K1)=K1
      PRINT 9011
 9011 FORMAT(* VARIABLES SET TO ONE*)
      PRINT 3830,(T(K),K=1,N)
 3830 FORMAT (15(4X,I3))
      ELT3 = T3 -T0
      NITER=NFATH+NFATH-1
      PRINT 3850,NOPT,NRED,NCON,NAUG,NAP,NID,NCID2
      PRINT 3851,NLPF,NSIMP,NITER,ELT3
 3850 FORMAT (23H0NO. FEASIBLE SOLUTIONS,I5/
     *         11H ZS GE ZBAR,I5,6H TIMES/
     *         22H CONSTRAINT INFEASIBLE,I5,6H TIMES/
     *         24H AUGMENTATION IMPOSSIBLE,I5,6H TIMES/
     *         22H AUGMENTATION POSSIBLE,I5,6H TIMES/
     *         14H INTEGER DUALS,I5,6H TIMES/
     *         26H NO. OF ROUNDED INT. DUALS,I5)
 3851 FORMAT (12H LP FATHOMED,I5,6H TIMES/
     *         10H LP CALLED,I5,6H TIMES/
     *         15H NO. ITERATIONS,I5/
     *         26H LAST FEASIBLE SOLUTION AT,F8.3,9H  SECONDS)
C  END OF FINAL OUTPUT. LOOK FOR ANOTHER PROBLEM NOW.
      GO TO 100
C  COMPLEMENT AND UNDERSCORE LAST REMAINING ENTRY IN S.
 3900 SB(L)=BCIB
      S(L)=-S(L)
      J=IABS(S(L))
      IF (S(L).GT.0) GO TO 3950
      ZS=ZS-C(J)
      DO 3925 I=1,M
 3925 BS(I)=BS(I)-A(I,J)
      GO TO 1910
 3950 ZS=ZS+C(J)
      DO 3975 I=1,M
 3975 BS(I)=BS(I)+A(I,J)
      END
      SUBROUTINE SIMPLE
C  AUTOMATIC SIMPLEX        REDUNDANT EQUATIONS CAUSE INFEASIBILITY
      COMMON INFLAG,MX,NN,A(133,90),C(90),B(133),KO(6),KB(90),P(90),
     1  JH(90),X(90),Y(90),OBJ,E(133,90),NOP
      COMMON BS(133),S(90),SB(90),NS(90),SMAX(90),SMAXB(90),
     1  T(90),CS(90),PE(90),ITEMP(4),JTEMP(4),ATEMP(4)
      COMMON MS(90),NF(90),ZBAR,IR,LPSEQ
      EQUIVALENCE (XX,LL)
      LOGICAL TRIG,VER
      LOGICAL FINV,FFRZ,SCH
C         SET INITIAL VALUES, SET CONSTANT VALUES
      FINV = .FALSE.
      TRIG = .FALSE.
      ITER = 0
      LPSEQ = LPSEQ+1
      NUMVR = 0
      NUMPV = 0
      M = MX
      N = NN
      TEXP  =  .5**16
      NVER  =  M/2  +  5
      NCUT  =  4*M + 10
      IF (INFLAG.EQ.0) GO TO 1410
C         IMPOSE CORRECT TEMPERATURE ON ROWS
      FFRZ =.TRUE.
      L = 1
  100   IF (MS(L).EQ.NF(L)) GO TO 1955
        IF(MS(L)*NF(L).GT.0.OR.(MS(L).EQ.0.AND.X(L).GE.0.)) GO TO 1950
        I=L
        IF (NF(L).NE.0) GO TO 1925
 1920   IF (JH(I).GT.0) GO TO 1930
C         IF JH DISAGREES WITH MS DO SPECIAL PIVOT
        IF (MS(L).GT.0.AND.JH(L).GE.(-M)) GO TO 1950
        IF (MS(L).LT.0.AND.JH(L).LT.(-M)) GO TO 1950
C  SPECIAL PIVOT, SWITCH SINGLETONS
 1925   DO 1926  J=1,M
          P(J) = P(J) + E(I,J)
          E(I,J) = -E(I,J)
 1926   CONTINUE
        OBJ = OBJ + X(I)
        X(I) = - X(I)
        JHL = JH(L)
        IF (JHL.GE.(-M)) JH(L) = -L-M
        IF (JHL.LT.(-M)) JH(L) = -L
        GO TO 1950
C       DO FULL PIVOT ON SINGLETON
 1930   JT = -I
        COST = P(I)
        IF (MS(I).GT.0) GO TO 1931
        JT = JT-M
        COST = 1.-COST
```

```
 1931   EN = 1.
        GO TO 630
C         GET COLUMN(JT)
 1932   SCH = .FALSE.
        IF (COST.GT.0.) GO TO 1938
 1935   GO TO 1000
C          SELECT ROW(IR)
 1936   IF (IR.NE.0.OR.SCH) GO TO 1940
        SCH =.TRUE.
 1938   EN =-EN
        DO 1937 J=1,M
          Y(J) = -Y(J)
 1937   CONTINUE
        GO TO 1935
 1940   IF((SCH.AND.ABS(COST).GT.TPIV).OR.IR.EQ.0)  GO TO 1980
 1941   IF (EN.GT.0.)  GO TO 1945
        DO 1942 J =1,M
          Y(J) = -Y(J)
 1942   CONTINUE
 1945   GO TO 901
C          PIVOT(IR,JT)
 1950   NF(L) = MS(L)
 1955   IF(JH(L).LT.0) GO TO 1960
        IA=JH(L)
        KB(IA)=L
 1960 CONTINUE
      L = L + 1
      IF (L .LE. M) GO TO 100
      FFRZ = .FALSE.
      GO TO 910
C*         START WITH SINGLETON BASIS
 1410 DO 1402  J=1,N
        KB(J) = 0
 1402 CONTINUE
      FFRZ =.FALSE.
 1400 DO 1401  I = 1,M
        JH(I) =-I
        NF(I) = MS(I)
        IF (NF(I).LT.0.OR.(NF(I).EQ.0.AND.B(I).LT.0.)) JH(I)=-I-M
 1401 CONTINUE
C*         CREATE INVERSE FROM #KB# AND #JH#      (STEP 7)
 1320 VER = .TRUE.
      INVC = 0
      NUMVR   =  NUMVR  +1
      TRIG = .FALSE.
      OBJ = 0.
      DO 1113  I = 1,M
        DO 1151  J=1,M
          E(J,I) = 0.
 1151   CONTINUE
        IF (JH(I).LT.(-M)) GO TO 1111
        IF (JH(I).GT.0) JH(I) = 0
        E(I,I) = 1.
        P(I) = 0.
        X(I) =  B(I)
        GO TO 1113
 1111   E(I,I) = -1.
        P(I)    = +1.
        OBJ = OBJ  + B(I)
        X(I)    = -B(I)
 1113 CONTINUE
      JT = 1
10101   IF (KB(JT).EQ.0)  GO TO 1102
        GO TO 600
C       GET COLUMN(JT)
 1114   TY = TPIV
        IR = 0
        COST = C(JT)
        DO 1104 I = 1,M
        COST = COST + A(JT,I)*P(I)
          IF(JH(I).NE.0.OR.X(I).NE.0..OR.ABS(Y(I)).LE.TY) GO TO 1104
          TY = ABS(Y(I))
          IR = I
 1104   CONTINUE
        IF (IR.NE.0) GO TO 1119
        TY = 0.
        DO 1105 I = 1,M
          IF(JH(I).NE.0.OR.X(I).EQ.0..OR.ABS(Y(I)).LE.TPIV) GO TO 1105
          IF (ABS(Y(I)).LE.TY*ABS(X(I)))  GO TO 1105
          TY = ABS(Y(I)/X(I))
          IR = I
 1105   CONTINUE
 1119   IF (IR.NE.0) GO TO 900
C       PIVOT(IR,JT)
        FINV = .TRUE.
      IF (NOP.EQ.0) PRINT 1199,LPSEQ
 1199   FORMAT(15H0INVERT FAIL LP,I4)
        GO TO 1410
 1102 CONTINUE
      JT = JT + 1
      IF (JT .LE. N) GO TO 10101
```

```
C* PERFORM A SIMPLEX ITERATION
 1200 VER = .FALSE.
  500 DO 503 I = 1,M
        IF (NF(I).EQ.0.AND.X(I).LT.0.) X(I)=0.
  503 CONTINUE
C*           FIND MINIMUM REDUCED COST                  (STEP 3)
  599 JT = 0
      BB  =  0.0
      DO 701  J =1,N
        IF (KB(J).NE.0)   GO TO 701
        DT = C(J)
        DO 303 I = 1,M
          DT = DT + A(J,I)*P(I)
  303   CONTINUE
        IF (DT.GE.BB)  GO TO 701
        BB = DT
        JT = J
  701 CONTINUE
      DO 702 I=1,M
        IF (JH(I).LT.0) GO TO 702
        IF (P(I).LT.BB) GO TO 703
        IF ((1.-P(I)).GE.BB) GO TO 702
        BB = 1.-P(I)
        JT = -I-M
        GO TO 702
  703   BB=P(I)
        JT = -I
  702 CONTINUE
      COST = BB
      IF (JT.EQ.0)  GO TO 203
      IF (ITER.GE.NCUT)  GO TO 160
      ITER = ITER +1
C*           MULTIPLY INVERSE TIMES A(.,JT)             (STEP 4)
      IF (JT.LT.0) GO TO 630
C     BEGIN SUBROUTINE GET COLUMN(JT)
  600 DO 610  I= 1,M
        Y(I) = 0.0
  610 CONTINUE
      DO 605   I= 1,M
        AIJT = A(JT,I)
        IF (AIJT.EQ.0.) GO TO 605
        DO  606  J = 1,M
          Y(J) = Y(J) + AIJT*E(J,I)
  606   CONTINUE
  605 CONTINUE
      GO TO 640
  630 JT2 = -JT
      EM = 1.
      IF (JT2.LE.M) GO TO 631
      JT2 = JT2 - M
      EM = -1.
  631 DO 632  I=1,M
        Y(I) = EM*E(I,JT2)
  632 CONTINUE
  640 YMAX = 0.
      DO 620  I  =  1,M
        YMAX = AMAX1( ABS(Y(I)),YMAX )
  620 CONTINUE
      TPIV  =  YMAX * TEXP
C     END OF GET COLUMN
      IF (FFRZ) GO TO 1932
      IF (VER)  GO TO 1114
      RCOST = YMAX/BB
      IF (TRIG.AND.BB.GE.(-TPIV)) GO TO 203
      TRIG=BB.GE.(-TPIV)
C*           SELECT PIVOT ROW                           (STEP 5)
 1000 AA = TPIV
      IR = 0
 1002 DO 1003 I = 1,M
        IF (X(I).NE.0..OR.Y(I).LE.AA.OR.NF(I).NE.0) GO TO 1003
        AA = Y(I)
        IR = I
 1003 CONTINUE
      IF (IR.NE.0) GO TO 1020
      AA = 0.
      DO 1010  I  = 1,M
        IF (NF(I).NE.0.OR.Y(I).LE.TPIV.OR.Y(I).LE.AA*X(I)) GO TO 1010
        AA = Y(I)/X(I)
        IR = I
 1010 CONTINUE
 1020 IF (FFRZ) GO TO 1936
      IF   (IR.EQ.0)   GO TO 207
C*           PIVOT ON (IR,JT)                           (STEP 6)
  901 IA = JH(IR)
      IF (IA.GT.0)   KB(IA) = 0
C     BEGIN SUBROUTINE PIVOT(IR,JT)
  900 NUMPV  =  NUMPV  +  1
      JH(IR) = JT
      IF (JT.GT.0)   KB(JT) = IR
```

```
      YI = -Y(IR)
      Y(IR) = -1.0
      DO  904  J = 1,M
        XY = E(IR,J)/YI
        IF (XY.EQ.0.) GO TO 904
        P (J) = P (J) + COST * XY
        E(IR,J) = 0.
        DO 906  I = 1,M
          E(I,J) =  E(I,J) + XY * Y(I)
  906   CONTINUE
  904 CONTINUE
      XY  =  X(IR) / YI
      DO 908  I  = 1, M
        XOLD = X(I)
        X(I) = XOLD + XY * Y(I)
  908 CONTINUE
      Y(IR) = -YI
      X(IR) = -XY
C     END OF PIVOT
      OBJ =  OBJ + XY*COST
      IF (VER) GO TO 1102
C       EXCHANGE ROWS IF SLACK PIVOTED IN WRONG ROW
      IF  (JT.GT.0.OR.JT2.EQ.IR) GO TO 907
      XY = X(IR)
      X(IR) = X(JT2)
      X(JT2) = XY
      DO 909 I =1,M
        XY =  E(IR,I)
        E(IR,I) =  E(JT2,I)
        E(JT2,I) = XY
  909 CONTINUE
      IA = JH(JT2)
      JH(JT2) = JT
      JH(IR) = IA
      KB(IA) = IR
  907 INVC   = INVC   +1
C   TO STEP 1 IF NOT INVERTING, TO STEP 7 IF INVERTING
      IF (FFRZ) GO TO 1950
      IF (OBJ.GE.ZBAR) GO TO 180
      IF (FINV) GO TO 1200
  910 IF (INVC.GE.NVER) GO TO 1320
      GO  TO  1200
C*  END OF ALGORITHM, SET EXIT VALUES              ***
  207 IF                 (RCOST.LE.(-1000.)) GO TO 203
C         INFINITE SOLUTION
      K  =  2
      GO TO 250
  180 K=6
      GO TO 250
C          PROBLEM IS CYCLING PERHAPS
  160 K  =  4
      PRINT 161,LPSEQ
  161 FORMAT(31H0ITERATION LIMIT EXCEEDED ON LP,I4)
      GO TO 250
C          FEASIBLE OR INFEASIBLE SOLUTION
  203 K  =  0
  250 DO 1399  J = 1,N
        XX  =  0.0
        KBJ  =  KB(J)
        IF (KBJ.NE.0)  XX = X(KBJ)
        KB(J) = LL
 1399 CONTINUE
      KO(1) = K
      KO(2) = ITER
      KO(3) = INVC
      KO(4) = NUMVR
      KO(5) = NUMPV
      KO(6) = JT
      IF (NOP.NE.0) RETURN
      PRINT 162,LPSEQ,(KO(I),I=1,6)
  162 FORMAT(3H LP,I5,6H   KO   ,6I6)
      PRINT 1982
 1982 FORMAT(21H0I   JH NF MS ,P,Y,X,B/1X)
      DO 1983 I=1,M
      PRINT 1984,I,JH(I),NF(I),MS(I),P(I),Y(I),X(I),B(I)
 1983 CONTINUE
 1984 FORMAT(1X,4I3,4F12.6)
      RETURN
 1980 IF (NOP.EQ.0) PRINT 1981,LPSEQ,L,IR,SCH,COST
 1981 FORMAT( 3H0LP,I4,12H FAIL, SLACK,I3,4H IR=I3,5H SCH=L1,3H C=F19.6)
      IF (IR.NE.0) GO TO 1941
      GO TO 1410
       END
```

APPENDIX C: RESULT OF SELECTION FOR A SINGLE AND MULTIPLE (IN THIS CASE 2) TIME PERIODS

```
*T=1,BALAS*

IMPLICIT ENUMERATION COMPLETE      TOTAL TIME=   1.118

SOLUTION BEFORE VARIABLE CHANGE Y(J) = 1 - X(J) IF C(J) IS NEGATIVE..
LEAST Z =  -15.75600000E+03
VARIABLES SET TO ONE
     0     2     0     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
     0    32     0     0     0    36     0    38    39    40    41    42    43    44    45

NO. FEASIBLE SOLUTIONS    2
ZS GE ZBAR    3 TIMES
CONSTRAINT INFEASIBLE    2 TIMES
AUGMENTATION IMPOSSIBLE    0 TIMES
AUGMENTATION POSSIBLE    6 TIMES
INTEGER DUALS    0 TIMES
NO. OF ROUNDED INT. DUALS    0
LP FATHOMED    0 TIMES
LP CALLED    0 TIMES
NO. ITERATIONS   13
LAST FEASIBLE SOLUTION AT    .936  SECONDS


* T=2

IMPLICIT ENUMERATION COMPLETE      TOTAL TIME=  53.213

SOLUTION BEFORE VARIABLE CHANGE Y(J) = 1 - X(J) IF C(J) IS NEGATIVE..
LEAST Z =  -54.54700000E+03
VARIABLES SET TO ONE
     0     2     0     0     0     0     0     0     0    10     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0    38    39    40    41    42    43    44    45
     0     0     0     0     0     0     0     0     0     0     0     0     0     0     0
     0     0     0     0     0     0     0     0     0     0     0     0    73    74     0
    76    77     0     0     0    81     0     0     0     0     0     0     0     0     0

NO. FEASIBLE SOLUTIONS    4
ZS GE ZBAR   11 TIMES
CONSTRAINT INFEASIBLE   46 TIMES
AUGMENTATION IMPOSSIBLE    5 TIMES
AUGMENTATION POSSIBLE   65 TIMES
INTEGER DUALS    0 TIMES
NO. OF ROUNDED INT. DUALS    0
LP FATHOMED    0 TIMES
LP CALLED    0 TIMES
NO. ITERATIONS  131
LAST FEASIBLE SOLUTION AT  25.947  SECONDS
```

*Projects to be implemented for the second plan period (τ = 2) are numbered 46 through 90.

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