MULTI-SECTORAL AND MULTIPLE OBJECTIVE MODELS FOR ECONOMIC DEVELOPMENT PLANNING—CASE OF SUDAN

by

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A DISSERTATION

submitted in partial fulfillment of the
requirements for the degree

DOCTOR OF PHILOSOPHY

College of Engineering
Department of Industrial Engineering
Kansas State University
Manhattan, Kansas

1980

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To my parents,

my brother and sisters,

my wife, and my

son and daughter.

ACKNOWLEDGEMENTS

I wish to express my deepest gratitude to my major advisor, Dr. C. L. Hwang for his encouragement and guidance of this work; to my committee members, Dr. F. A. Tillman, Dr. D. L. Grosh, and Dr. K. R. Akkina; and to the committee chairman, Dr. D. Johnson.

I would like also to thank Ms. Merla Oppy for typing the manuscript. Special thanks to Mrs. Catheryn Long for the numerous services and help she rendered to me during the five years of my study.

I also acknowledge the financial support of the Government of the Democratic Republic of the Sudan.

To my parents, brother, and sisters, I will be indebted always for their sacrifices, strong encouragement, and support.

I am also grateful to my wife, Afaf, for her continued encouragement and patience throughout the years of graduate school; to my daugher, Hala, and my son, Hani, for their childhood evenings and weekends that they sacrificed so that their father could study.

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CHAPTER I

INTRODUCTION

The selection of the problem of economic development planning for Sudan in this study is dictated by the following factors: firstly, this problem is a source of frustration not only to Sudan but also to many other developing nations; secondly, literature and data in this field are more available than for other problems; thirdly, the author is familiar with some of the development plans for Sudan. The author's experience with the planning process started in the year 1970 while being in charge of the preparation of the manufacturing sector's plan and its coordination for the country's second comprehensive economic development plan, the five-year plan (1970/71-1974/75). Also, the author participated in the discussions and evaluations of the "Interim Action Program" during the years 1973 and 1974 when working in the preparation and steering committees for the"First Sudanese Engineers National Conference".

From this short experience and from the literature surveyed one would doubt the effectiveness of the planning process, if any exists, for Sudan. What is meant here by the planning process, is the application of a rational system of choices among feasible courses of investment and other development actions, while the principal agents of a planning process can be conceived as to encompass: policy makers, planners, statisticians, and researchers. The flow of information between these agents is multilateral, involving important feedback at all levels. The ineffectiveness may be due, among other things, to either the nonexistence of the last three agents or to their being superceded by the first agent. Rational choice has no meaning when the alternatives are derived in the absence of some model, since plans are rarely developed without some formal economic models to help planners to learn more about the aggregate problems and intersectoral relations of the growth and

development process. Planners need also to use the results from such models as part of the information flow between them and the policy makers. This ineffectiveness may be responsible for the deviations from what is planned and the termination of all the plans before the end of their periods.

Beside the conceptual problem, the framework for planning in Sudan is also deficient. As an example, the five-year plan had been put to public debate in the year 1970 before its discussion and coordination within the different ministries and other bodies whose individual plans are usually highly dependent on others. Also, the "Interim Action Program" had been adopted for some years before transferring it into a form of a consistent and feasible plan.

The major objective and contribution of this study is to demonstrate that the planning process in Sudan can greatly be improved, even in the absence of complete data, by following a few simple scientific techniques. The study will simulate the planning process where the activities of the four principal agents are incorporated. The approach will be to: model the economy, relate planning to implementation, and finally apply multiple objective decision making (MODM) models and methods.

Modeling The Economy

Input-output modeling methodology will be used in this study because the technique can be transformed easily into a consistent mathematical model. Due to the absence of a recent input-output table, and also to avoid borrowing other countries' tables, the study will devise a new methodology for constructing a new input-output table for Sudan from an existing obsolete table. The methodology makes use of historical data available in the form of annual national income accounts. Lecomber (1971), in a critique of the methods of adjusting, updating, and projecting matrices, notes the failure of these methods to utilize the range of information generally available. The

methodology of this part is not only original in that it leads to the development of a new table from an obsolete one, but its application can extend to borrowed tables. It can also contribute to the development of an adaptive fitting technique of input-output tables for developing countries.

For most developing countries, however, the problem is not only the absence of a recent table, but also the nonavailability of accurate and reliable statistics in a form suitable for direct insertion into an input-output table. This is the situation faced in this part of the study where in some instances the data is compiled from detailed statistical publications.

Planning and Implementation

Shen (1975) suggests that a new constraint representing the capability of the government of a developing country to implement the plans should supersede the constraints imposed by scarce resources. The answer to this suggestion can be found in the argument by Frisch (1962): that it is useful for practical purposes to consider separately the selection problem and the steering or implementation problem which are involved in an overall planning problem. The selection problem, according to Frish, can be stated as:

> "A selection model is primarily useful for the purpose of describing a constellation of the volume figures or the figures in actual technical units which has been realized or might be realized or one would like to see realized, provided one can find ways and means (institutional, administrative and financial) of bringing this constellation about."

On the other hand, the implementation problem is to find how to steer the economy (i.e., what institutional arrangements to make, which economic policies and measures to use, and how to use them) in order to achieve the real economic

constellation selected as being the best one. The optimization of such an overall planning problem can be performed in one of two ways: in two stages or in one stage. In the two stage approach we first find the optimal solution to the selection problem (the state variables) which consists of, for example, a preference function, resource limitations, balance relations, and production relationships; the second stage is to find the optimal solution in the implementation problem (the instrument variables) which produces the results arrived at in the first stage. In the one stage approach the problem is to find the optimal solution of the overall planning problem when expressed in terms of both the state and instrument variables (assuming the targets and instruments are flexible).

The optimization of the selection model does not usually pose any difficulty as the problem is amenable to formalized and quantitative analysis. However, the implementation problem may not be reliably represented in a formalized model, and consequently it may prove more practical to rely on intuition and practical judgment and experience instead of optimization. The selection model by itself is useful only if there is a high probability of selecting a result which will prove feasible to implement. The planning models in socialist countries tend to be of the nature of the selection models. In other situations the results from the selection problem are usually unrealizable in practice, therefore, the choice is either to try to change the institutional, administrative, and financial structure (if they constitute the difficulties for implementation and attainment of goals), or lower the set of goals.

Most of the plans of Sudan are characterized by highly set goal levels without due consideration to their feasibility and consistency, not to mention optimality. Also there is no clear or precise coupling of the

planning and implementation problems, although the latter constitutes the biggest obstacle to plan realization. The solution of a model incorporating all elements and aspects of the implementation problem of Sudan will be quite formidable. Consequently the study will include only some of the quantifiable economic policies and measures with the idea that both targets and instruments (policy variables) are flexible. Also plans in Sudan and other developing countries are usually considered as blueprints instead of regarding them as working plans to be reviewed constantly and revised periodically. Thus this study will attempt to introduce a correction to this misunderstanding and other implementation problems by intrinsically incorporating them in the modeling methodology and construction.

MODM Models and Methods

It is very rare to find a comprehensive development plan with only a single objective; most of the time many objectives of conflicting nature are included in a plan: the best decision with respect to one objective may not be optimal for others. For Sudan the objectives range from five to sixteen in the three plans developed so far.

The development planning problem of Sudan will be approached by two linear MODM models; the first is a terminal year model (TY), and the second is a year-by-year (YBY) model. In the TY model the terminal conditions are endogenously determined from the specification of the base year values and the exogenous values; the model thus aggregates over time to reflect the scope of investments and other requirements during the plan period. The YBY model is to complement the first model by interactively tracing the development planning path (interactive path control) followed to reach these terminal conditions.

MODM methods have been recently classified (Hwang and Masud, 1979) into four categories according to the articulation of preference information given: none, a priori, progressive, and a posteriori. In spite of the fact that methods from the third category might be more suitable for developing countries where the interactivity or DM-Analyst dialogue at each iteration induces the DM to learn more about the problem, Tantasuth (1975), Yoon (1977), and Masud (1978) used GP from the second category, although the latter used a new interactive method (ISGP). Others (Spivey and Tamura, 1970; Wallerius et al, 1976; Despontin and Vincke, 1977) used either the second or the third for solving annual economic policies with econometric models for the U.S. and Finland.

From the third category the step method (STEM) by Benayoun et al (1971) will be used for solving the two MODM models of Sudan. Another method from the same category, namely the method of satisfactory goals, will also be used for solving the two models.

A characteristic of this study is in the attempt to make the plans of developing countries operative, operative in the sense that the use of two MODM models provides a flexibility of the planning process; the TY model provides the scope under the given potentials and restrictions while the YBY model provides a dynamic MODM methodology (with respect to time) with feedback. The study is expected also to contribute in improving some of the MODM methods.

Organization of Contents

Chapter II presents the basic theory of input-output models, how input-output tables are prepared and maintained, and their relationship to the national accounting system. The different planning models in use, and the criteria for choosing a model are also presented. The experience of some developing countries with input-output models is surveyed.

In Chapter III the development plans of Sudan are critically reviewed and compared. The three development plans of Sudan are exposed with respect to their formulation and the problems in their implementation. A diagnostic approach is followed in order to find the common problems of the three plans with respect to formulation and operation.

In Chapter IV, first a survey of the existing models of Sudan is made, then the RAS method of updating input-output tables is explained in detail with its algorithm, flow diagram, and a computer program stated. Finally the methodology of developing the new input-output table for Sudan is stated in step by step form. Real data is used to construct the new input-output table.

In Chapter V two MODM models for the development planning problem of Sudan are constructed. The first is a terminal year model (TY) which aggregates the plan through time, while the second is a dynamic year by year (YBY) MODM model. The construction of the models is such that the actual data of the six-year plan (1977/78-1982/83) can be used in the solutions. Two MODM methods are then used to solve the two models. Finally the results by the two models from the two methods and the actual plan figures are compared.

Chapter VI presents a summary, concluding remarks, and proposed future studies.

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CHAPTER II

INPUT-OUTPUT ECONOMIC MODELS: AN OVERVIEW

1. INTRODUCTION

Although the origin of input-output analysis can be traced back to Francois Quensnay's Tableau Economique of 1758 the first empirical application of the input-output model in the U.S.A. was in 1936 when Leontief published an input-output system of the United States economy. Leontief's input-output method has been one of the best contributions to both theoretical and empirical economics. The post-war reconstruction period led to its application in countries like Norway, the Netherlands and Italy. Some countries in Asia and Africa starting their development programs mostly used input-output techniques from the beginning. The development of electronic computers has also made the application of input-output models to empirical problems more practical.

Input-output technique breaks the economy into sectors or industries, and the flow of goods and services among sectors or industries is recorded to indicate the systematic relations among the sectors or industries; the relations are known as input-output relations because they tell what inputs a sector needs to produce its output. Thus the input-output technique by disaggregating an economy into finer units is capable of tracing out effects not possible to detect in macroanalysis.

A profound grasp of input-output techniques requires a thorough understanding of the basic structure of an input-output table which is the basis of all input-output work. An input-output table is defined as a collection of data describing the particular structural characteristics of any economic system, and/or as an analytic technique for explaining and influencing the behavior of the system at a certain point in time or over the course of time. Its major theoretical and practical value is that it can easily be transformed into a consistent mathematical model and utilized either as a forecasting tool or as a framework within which consistent and comprehensive

economic plans can be drawn up and carried out. Input-output tables, however, require a great deal of statistical data for their development.

2. BASIC THEORY OF INPUT-OUTPUT MODELS

2.1 Basic Identities

The most simplified illustration of the main blocks in an interindustry table is shown in Figure 1.

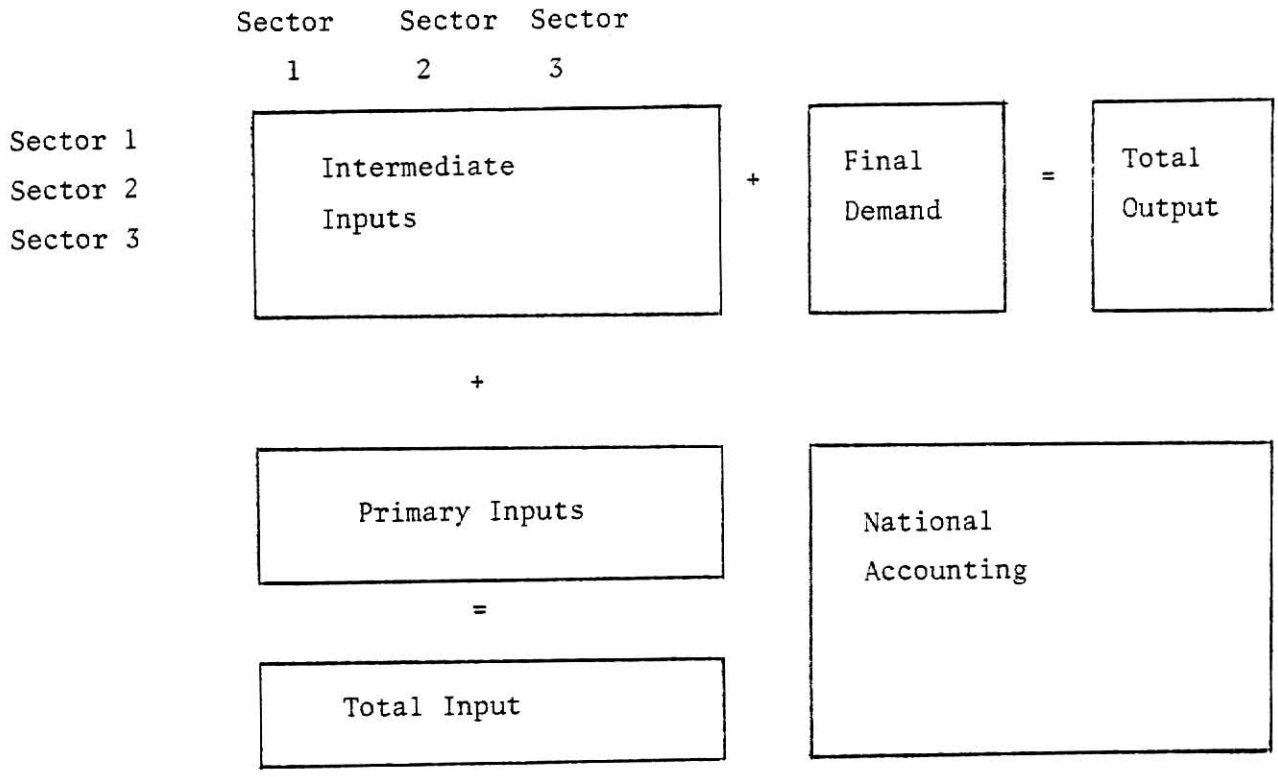

Figure 1. Basic Blocks of an Input-Output Table.

The intermediate inputs block shows the delivery of output from each sector (industry) to all sectors of the economy for use in the production of each sector. The primary inputs block represents the primary inputs (indirect taxes, labor, depreciation, profits, and imports) to each of the sectors. The sum of these two blocks is the total input block.

The final demand block represents the part of outputs by each sector devoted to final use. The sum of the corresponding rows of the intermediate inputs and final demand blocks is the total output by each sector.

The last block of national accounting, or the direct factor purchase block, is only necessary for accounting purposes -- e.g., measuring gross domestic product.

For a better illustration of the input-output table, a simple hypothetical economy consisting of three sectors -- agriculture, manufacturing, services -- will be considered. Table 1 is a numerical example. Each sector (for the moment ignoring the figures in parentheses) appears as a producer of output and a user of inputs. For example, the manufacturing sector produces 465 units of which the agricultural sector uses 12 units as one of its inputs, manufacturing uses 3 units (the table is more or less a representation of a developing economy), and the services sector uses 30 units. The three sum to 45 units (12 + 3 + 30 = 45) of output by manufacturing delivered as an intermediate input (intermediate demand) to the other two sectors and itself. Columns 6 to 9 show the deliveries of the manufacturing sector to each of the final use (final demand) sectors (household, government, capital formation, and export); these total to 420 units (320 + 20 + 40 + 40 = 420) of total final demand.

Column wise, the manufacturing sector, in order to produce 465 units of output, must use 100 units of agriculture output, 3 from its own output,

Table 1. A Hypothetical Input-Output Table

	Inputs		Intermediate Inputs				Final Demand					Total Output
	Outputs		Agriculture 1	Manufacturing 2	Services 3	Total Intermediate Demand (1+2+3) 4	Household Consumption 5	Government Consumption 6	Capital Formation 7	Export 8	Total Final Demand (5+6+7+8) 9	(4+9) 10
Producing Sector	Agriculture	1	20 (5)	100 (15)	25 (15)	145 (35)	1797 (35)	90 (10)	330 (10)	200	2417 (55)	2562 (90)
	Manufacturing	2	12 (2)	3 (20)	30 (5)	45 (27)	320 (35)	20 (3)	40 (10)	40	420 (48)	465 (75)
	Services	3	200 (5)	67 (25)	120 (5)	387 (35)	573 (30)	180 (10)	400 (20)		1153 (60)	1540 (95)
	Total Produced Inputs (1+2+3)	4	232 (12)	170 (60)	175 (25)	577 (97)	2690 (100)	290 (23)	770 (40)	240	3990 (163)	4567 (260)
	Imports	5	90	75	95	260	[100]	[23]	[40]		[163]	260
	Indirect Taxes (Government)	6	40	40	200	280	[10]	[5]			[15]	280 [295]
Value Added	Labor (Household)	7	2000	100	800	2900	50	20			70	2970
	Capital (depreciation)	8	200	80	270	550						550
	Value Added (6+7+8)	9	2240	220	1270	3730	50	20			70	3800
	Total Input	10	2562	465	1540	4567	2740 (100)	310 (23)	770 (40)	240	4060 (163)	8627

and 67 from the services sector, i.e., a total of 170 units of produced inputs (100 + 3 + 67 = 170). In addition the manufacturing sector must import 75 units and use 220 prime input units (labor and capital), thus making a total input of 465 units (170 + 75 + 220 = 465) which is equal to gross output. The entries of Table 1 can be either in physical quantities or in money value; in this example we take them as money values, and an explanation will be made later in the chapter.

Imports are usually shown as a row vector (row 5 in Table 1), but for clarification, especially for the case of a developing country, it is broken down in detail and included in each cell between parentheses. This is as if we have two input-output tables -- one for domestic products and the other for imported products. This disaggregation of imports is usually not practical, although the impact of demand on domestic and foreign supplies can be thoroughly analyzed, and in the case of developing countries they provide a deeper insight into the economy and aid in the planning process.

To develop the mathematical relations Table 1 is written in symbolic terms as Table 2 (neglecting the import matrix). The output of the three sectors as inputs intermediate to each other and to final use is represented by the following equations:

$$\begin{aligned} X_{11} + X_{12} + X_{13} + Y_1 &= X_1 \\ X_{21} + X_{22} + X_{23} + Y_2 &= X_2 \\ X_{31} + X_{32} + X_{33} + Y_3 &= X_3 \end{aligned} \qquad (1)$$

An implicit assumption in Equation (1) [BM6, 43] is that each sector produces a single good which can be used interchangeably for consumption, investment, as an export, as an intermediate good, etc. A second assumption is that a

Table 2. A Hypothetical Input-Output Table in Symbols

Inputs		Intermediate Inputs				Final Demand					Total Output
Outputs		Agriculture 1	Manufacturing 2	Services 3	Total Intermediate Demand (1+2+3) 4	Household Consumption 5	Government Consumption 6	Capital Formation 7	Export 8	Total Final Demand (5+6+7+8) 9	(4+9) 10
Agriculture	1	x_{11}	x_{12}	x_{13}	$\sum_{j=1}^{3} x_{1j}=W_1$	y_{11}	y_{12}	y_{13}	y_{14}	$\sum_{f=1}^{4} y_{1f}=Y_1$	X_1
Manufacturing	2	x_{21}	x_{22}	x_{23}	$\sum_{j=1}^{3} x_{2j}=W_2$	y_{21}	y_{22}	y_{23}	y_{24}	$\sum_{f=1}^{4} y_{2f}=Y_2$	X_2
Services	3	x_{31}	x_{32}	x_{33}	$\sum_{j=1}^{3} x_{3j}=W_3$	y_{31}	y_{32}	y_{33}	y_{34}	$\sum_{f=1}^{4} y_{3f}=Y_3$	X_3
Total Produced Inputs(1+2+3)	4	U_1	U_2	U_3	U	$\sum_{i=1}^{3} y_{i1}$	$\sum_{i=1}^{3} y_{i2}$	$\sum_{i=1}^{3} y_{i3}$	$\sum_{i=1}^{3} y_{i4}$	Y	X
Imports	5	M_1	M_2	M_3	$\sum_j M_j=M$						
Indirect Taxes (Government)	6	T_1	T_2	T_3	T						
Labor (Household)	7	L_1	L_2	L_3	L						
Capital (depreciation)	8	K_1	K_2	K_3	K						
Value Added (6+7+8)	9	V_1	V_2	V_3	$\sum_j V_j=V$						GNP
Total Input	10	X_1	X_2	X_3							

single process production function exists in every industry. This is quite a strong assumption; it implies that there are constant returns to scale and that no substitution among inputs is possible. This leads us to the definition of the constant "technical coefficients of production". For example, in Table 1 we can see that in order to produce 465 units of total output, the manufacturing sector must purchase 12 units of agricultural output for its intermediate inputs. This means that for every unit of manufacturing output $0.026 (= \frac{12}{465})$ units of agriculture output will always be needed. Similarly, .065 units of output is needed from the services sector. Mathematically these can be stated as $a_{21} = \frac{X_{21}}{X_1}$, $a_{23} = \frac{X_{23}}{X_3}$, $a_{22} = \frac{X_{22}}{X_2}$ or generally $a_{ij} = \frac{X_{ij}}{X_j}$ = constant (technical coefficients of production) where

i, j = number of sectors in the table.

Thus we can write:

$$X_{ij} = a_{ij} X_j$$

and substituting in the set of equations in (1) for X_{ij} we have:

$$\begin{aligned} a_{11} X_1 + a_{12} X_2 + a_{13} X_3 + Y_1 &= X_1 \\ a_{21} X_1 + a_{22} X_2 + a_{23} X_3 + Y_2 &= X_2 \\ a_{31} X_1 + a_{32} X_2 + a_{33} X_3 + Y_3 &= X_3 \end{aligned} \qquad (2)$$

or $$X_i = \sum_{j=1}^{3} a_{ij} X_j + Y_i \qquad (3)$$

or in matrix and vector notations:

$$AX + Y = X \qquad (4)$$

where A is an n x n square matrix of technical coefficients of production.

By rearranging we obtain the well known Leontief matrix, (I - A):

$$(I - A)\ X = Y \tag{5}$$

and solving for X we have:

$$X = (I - A)^{-1}\ Y \tag{6}$$

Equation (6) is the core of the input-output table since usually we know A, and we decide on Y and must find X.

This mathematical manipulation could also be extended to the other blocks to obtain the necessary coefficients, i.e., we can find the coefficients for imports, indirect taxes, labor etc.:

$$m_i = \frac{M_i}{X_i}$$

$$t_i = \frac{T_i}{X_i} \tag{7}$$

$$\ell_i = \frac{L_i}{X_i}$$

2.2 Uses of Input-Output Tables

The major theoretical and practical value of an input-output table is that it can be easily formulated into a consistent mathematical model which can be utilized as an analytic and forecasting tool in market economics, and as a framework for consistent and comprehensive economic development planning as in centralized economics.

Input-output analysis can tell the effect on output of a given change in final demand. The inverse matrix of Equation (6), $(I - A)^{-1}$, could be used to assess the effect on the productive system of a given level of final demand. The impact on the productive system due to any change in the components of final demand or primary inputs can also be analyzed; for example, a change in final demand, ΔY, on total output:

$$\Delta X = (I - A)^{-1} \Delta Y, \tag{8}$$

the impact of this change on employment in the economy:

$$\Delta L_T = \sum_{i=1}^{n} \ell_i \Delta X_i \tag{9}$$

or the effects on imports:

$$\Delta M_T = \sum_{i=1}^{n} m_i \Delta X_i \tag{10}$$

Input-output tables can thus be used to check intersectoral and final demand consistency for national income accounts. They can also show the sources and uses of government funds and the current account of the balance of payments

For planning purposes input-output analysis has become the most widely used technique; this will be covered later.

2.3 Input-Output Tables and National Income Accounts

The national-income accounts record all the final goods and services produced in an economy during a specific year by each of the following four sectors: Business, household, government, and export (the rest of the world). The data for these sectors (columns no. 4, 5, 6, 8 of Tables 1 and 2 are found in the "value added" row (row 9 of Tables 1 and 2) of an input-output table. The national-income accounting is also a systematic summary of economic activation, except that it differs from input-output in detail and method since the input-output table usually divides the business sector into many industries. The two systems are in fact complementary, and nearly all the information pertaining to national-income accounts is also obtainable from an input-output table. However, the converse is not true as the national-income accounts are concerned with national totals rather than individual industries. The Gross Domestic Product (GDP) can also be computed from expenditures which are divided into household consumption, capital formation, government expenditures, and net exports in a table of national-income accounts. The same result can be found from an input-output table (columns 5, 6, 7, 8 in row 10 minus imports in row 5 and column 10). The other national-income accounts, like Net National Product (NNP) and National Income (NI), can also be obtained from an input-output table since:

NNP = GDP - depreciation*

NI = NNP - indirect business taxes**

Mathematically the relation between input-output accounts and the national

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* Row 8 and Column 4 figures in Table 2.1 and 2.2.

** Row 6 and Column 4 figures in Table 2.1 and 2.2.

income aggregates can be developed as follows:

For the rows of Table 2 we have:

$$X_i = \sum_j X_{ij} + Y_i, \tag{11}$$

and for the columns we have

$$X_j = \sum_i X_{ij} + M_j + V_j \tag{12}$$

Adding up each of the balance equations above for rows and columns respectively:

$$\sum_i X_i = \sum_i \sum_j X_{ij} + \sum_i Y_i \tag{13}$$

$$\sum_j X_j = \sum_j \sum_i X_{ij} + \sum_j M_j + \sum_j V_j \tag{14}$$

Since $\sum_i X_i = \sum_j X_j$, therefore equating Equations (13) and (14), and eliminating we get the basic national accounts identity - the gross domestic product (GDP):

$$\sum_i Y_i - \sum_j M_j = \sum_j V_j \tag{15}$$

This is also the "value added", which usually includes wage payments, depreciation (cost of using capital equipment), business taxes, rent, interest, and profit or loss.

3. DYNAMIC INPUT-OUTPUT MODELS

The input-output models we have considered so far are "static" input-output models which neglect entirely the effect of the time element. Also the model considers investment as an autonomous final demand like private consumption, government consumption etc. It must, however, be realized that the relation between capital accumulation and output is subject to a considerable variation depending on which of the following three assumptions is used [BM1, p. 71]:

1. building ahead demand by industry,
2. operating at some level of "economic capacity", or
3. forced-draft operation near the maximum technological capacity.

There are also many ways to overcome production bottlenecks, e.g., by:

1. varying final demand, or
2. using substitute materials, or
3. working overtime, or
4. expanding existing plants, or
5. building new plants.

In most of the work with input-output models the assumption is usually that excess capacity in each sector is zero. Dynamic input-output models [BM1, p. 71] have been proposed by Hawkins (1948), Leontief (1953a), and by members of the U.S. Airforce planning staff, as reported in Holley (1953). Although dynamic models are generally superior to static models , [BM8, p. 141] because the former are capable of tracing the path of economic growth, they face some data and computational limitations and other problems.

The development of a dynamic input-output model from a static model can be summarized as follows:

Instead of writing the input-output balance equation, equation (3), as

Gross output = Intermediate demand + final demand

we can rewrite it as:

Gross output = Intermediate demand + Induced investment + final demand.

To obtain the relation for the second term on the right-hand side of the above balance equation let $S_{ij}(t)$ represent the stock of commodity i, produced by sector i, purchased as capital goods by sector j at time t. The rate of increase in that stock from (t - 1) to period (t) = $S_{ij}(t) - S_{ij}(t-1)$. The new balance equation is

$$X_i(t) = \sum_{j=1}^{n} a_{ij} X_j(t) + \sum_{j=1}^{n} [S_{ij}(t) - S_{ij}(t-1)] + Y_i(t) \qquad (16)$$

If we adopt the same methodology for explaining the intermediate flow equations ($X_{ij} = a_{ij} X_j$) by constructing a corresponding set of n x n structural capital stock relationships for S_{ij}, i.e.,

$$S_{ij} = b_{ij} X_j \qquad (17)$$

where b_{ij}'s are the economic system's capital coefficients, i.e., the amount of capital input needed per unit of output for sector j, then we can have n x n matrix of subsectoral capital coefficients, B, as the square matrix, A, of technical coefficients of production:

$$S_{ij}(t) - S_{ij}(t-1) = b_{ij}[X_j(t) - X_j(t-1)] \qquad (18)$$

Substituting equation (18) into equation (16) gives

$$X_i(t) = \sum_{j=1}^{n} a_{ij} X_j(t) + \sum_{j=1}^{n} b_{ij}[X_j(t) - X_j(t-1)] + Y_i(t) \qquad (19)$$

or in matrix and vector notation:

$$\underline{X}(t) = \underline{A}\,\underline{X}(t) + \underline{B}[\underline{X}(t) - \underline{X}(t - 1)] + \underline{Y}(t) \qquad (20)$$

which is the dynamic model in matrix and vector form.

4. PREPARATION OF INPUT-OUTPUT TABLES

What has been mentioned in the previous pages is the basic theoretical framework of an input-output table; in the hypothetical example only three production sectors were assumed. Generally, however, the input-output tables break an economy into many sectors, and in addition the actual productive structure of an economy is much more complicated than our example shows. Thus in practice a numerical input-output table for a real-world economy is often enormous and complicated. This is because there are many problems, both statistical and conceptual, which are usually encountered in the preparation of an empirical table; these problems may be problems of aggregation, classification, and manipulation of statistical data. Conceptual problems arise as to whether the value figures in the table are to be stated in producer's or purchaser's prices, how to treat imports (competitive and noncompetitive), what is to be done with unallocated inputs and outputs, etc. The treatment of all these problems is anyhow arbitrary, although some rules of procedures must be established; these rules are usually set according to the availability of data.

An input-output table should be constructed in physical terms [BM9, p. 59] in order to reflect the true technological aspects of production. Although is it theoretically possible to construct such a table, in practice it is extremely difficult and the best common measure is money value of output. The advantage in using money units is that we can sum over a column as well as a row.

The most practical source of statistical information to construct an input-output table is an industrial census (an overall census of the economy) which collects detailed information on inputs and outputs of the individual industries [BM1, p. 140]. Although a large volume of output data can be obtained from other sources like the national-income statistics, a

census is the only way to provide input data in sufficient generality and with sufficient detail. The table is usually referred to by the year of census.

Before designing a statistical system for an industrial census [BM8, p. 88], some essential points should be considered, e.g.,

1. the ultimate use of the table,
2. the availability of data,
3. coordination of the efforts between the organizations or individuals conducting the census,
4. the intended classification of sectors for the economy in order to determine the level of detail of the worksheets.

The procedures for constructing an input-output table [BM9, p. 63] can be listed as follows:

1) Selecting a definite time period to be covered.
2) Classifying sectors or industries.
3) Establishing output totals for each sector or industry to be used as control totals.
4) Tracing the intersectoral of interindustrial flow of goods and services.
5) Cross-checking, reconciliation and adjustment of all entries.

5. PRACTICAL APPLICATIONS

The input-output tables can be utilized to analyze the economic impact due to a change in final demand and thus aid policy makers in decision making. Questions as to the effects of a change in final demand on the level of total industrial employment in the economy and on the balance of payments can readily be answered. When the resources of an economy are fully utilized or limited in quantity in the short run, then bottlenecks will appear for some expansion in output. Input-output analysis will then aid in detecting such possible bottlenecks, and appropriate measures can be taken. The analysis can also show the relation between imports and national income. A variation in the composition of final demand may affect imports without a change in the level of income [BM1, p. 55]. The separate effects of a change in the proportions of investment, consumption, and exports or imports in gross national product can be detected.

The effects of any change on the input side can also be analyzed. The changes in the prices of output of each sector due to a change in the rates of payment to the primary inputs (labour and capital) can be estimated. The relation between the prices and primary inputs [BM8, p. 124] is:

$$p = (I - A')^{-1} (\underline{w} + \underline{\gamma}) \tag{21}$$

where p is a vector of the price per unit of the n products, A' is the transpose of A, $\underline{w}$ and $\underline{\gamma}$ are the vectors for wages and profits, respectively. For example, what are the effects of increasing the wages in sector 3 by 10%? The same arguments can also be extended to the effects of increasing indirect taxes.

Input-output analysis has become perhaps the most widely used tool of economic analysis for planning purposes [BM4, p. 25]. The role played by

input-output tables in planning can be summarized in three points [BM8, p. 133]:

1. It provides an estimate of the intermediate demand for commodities required to meet the postulated level of final demand.
2. It is used to a greater or lesser extent to make the division between imports and domestically-produced goods.
3. It is used in determination of price levels.

The use of the static input-output models in development planning has a drawback. This is because the static input-output model considers investment an autonomous final demand like consumption, government spending, export etc..., which is not true in development planning. However, by using a dynamic input-output model this drawback is avoided [BM7, p. 80].

6. DEVELOPMENT PLANNING AND INPUT-OUTPUT MODELS FOR DEVELOPING COUNTRIES

Generally economic plans are formulated in accordance with some particular mathematical or statistical model which is thought to be most representative of the unique structural conditions in an economy during the intended planning period. Economic models can be micro, aggregate or macro. Whatever model is used, it will usually provide a logically systematic and internally consistent operational framework based on an important set of structural interrelationships in the economy.

Planning modes can be classified into three basic categories according to the degree of structural complexity and the use to which the model is put [BM7, p. 10]. The order in increasing complexity is:

1. the aggregate model which deals with the entire economy in aggregate components such as consumption, production, investment, saving, exports, imports etc. The well known Harrod-Domar is such a model.
2. the sectoral model which has two different approaches to development programming. One approach is to divide the economy into two or more main sectors. The second approach is to have a sector-oriented model.
3. the interindustry model which is highly disaggregative with quantifiable relationships between the various sectors of the economy. A simple taxonomy of the planning models of this type [BM5, p. 796]is:
    1. input-output models
    2. simultaneous equation models of a behavioral nature
    3. models combining both features of input-output models and behavioral models.

A developing country's choice of a planning model depends on a number of considerations, e.g.,

1. Stage of development
2. Institutional structure
3. Availability and quality of statistical information
4. Operative constraints
5. Objectives and priorities

In almost all countries (developed or developing) in which planning models have been constructed, input-output analysis has been used [BM4, p. 25]. Some doubt the usefulness of constructing input-output tables for some developing economies [BM2, p. 201] due to the drastic lack of statistics and the fact that intermediate material transactions are negligible (empty boxes or zero interindustry transactions) compared to economies that have achieved a certain degree of industrial development. However, although detailed or large input-output tables may not be available for developing countries the preparation of a rough input-output table is often a useful way to organize the data that do exist and to locate statistical inconsistencies and deficiencies; even the existence of empty boxes provides an excellent means to evaluate the introduction of new industries. To apply input-output techniques in developing countries some modification has to be introduced to the basic framework used in developed countries. For example, developing economies are oriented towards foreign trade, and thus estimates of import requirements, import substitution etc. are essential. Other questions or objectives pertaining to developing countries are: the choice among export in promotion alternatives, labor and manpower analysis, efficient investment allocation, etc.

Developing economies usually face some resource limitations or constraints; hence not only the consistency provided by input-output analysis is needed, but also the making of efficient choices among alternative

uses of resources. Thus the complementary technique of linear programming for development planning can also be used.

Table 3 shows the countries which have compiled national input-output tables [BM8, p. 160]. Table 4 shows 18 countries which used optimization techniques for input-output models in development planning [1, p. 65].

India, as one example among developing countries, found the input-output approach to be ideally suited to a comprehensive planning effort [BM3, p. 12]. The first input-output table (12 x 12) was constructed for India in the Indian Statistical Institute under the direction of Goodwin and Choudhung in 1950.

In Africa a few countries have input-output tables. The first input-output table for Egypt was constructed in 1954 [BM2, p. 199]; the table contains 83 productive sectors which were aggregated to 33 and then to 7 sectors. Final demand is composed of six sectors: household consumption, government consumption, capital formation by private sector, capital formation by government, stocks, and exports. The transactions are valued at producer's prices, imports on c.i.f., and export on f.o.b. Inputs of domestic origin are separated from imports in each cell. The interdependence of the sectors was found to be very high, 542 from 1056 cells containing entries from domestic production. This represents about 50% compared to 73% in Italy, which is more developed than Egypt. Eleish [BM2, p. 202] also cited the input-output matrices of some African countries where, for example, the Gold Coast had only 3 out of 30 cells receiving deliveries from domestic production.

When adopting input-output techniques in developing countries an important feature should not be overlooked. Input-output tables need to be revised or updated for developed as well as developing countries, but

Table 3 Classes in the input-output table. Catagories of final demand and categories of primary input. [BM 8]

Country	Year to which analyzed input-output table refers	Basic tables available		Ind. and comm. categories				Categories of final demand				
				Number of classes		Classification		Sum of consumption and gross fixed capital formation	Sum of public and private consumption	Sum of public consumption and public gross fixed capital formation	Private consumption	Public consumption
		Comprehensive input matrix	Supplementary ind. x comm. output matrix	Comm. rows	Ind. columns	National	Other					
		1	2	3	4	5	6	7	8	9	10	11
1. Algeria	1954	x	x	25[1,2/]	25	x		x				
2. Argentina	1960	x		28	28	x					x	x
3. Australia	1958/59	x		34	34	x				x	x	
4. Austria	1961	x		40	40	x					x	x
5. Belgium	1965	x	x	155	81	x	NIMEXE NACE				x	x
6. Bolivia	1958	x		10	10	x					x	x
7. Brazil	1959	x		32	32	x					x	x
8. Bulgaria	1963	x		19	19	x			x[7/]			
9. Canada	1961	x	x	644[3/]	187[3/]	x				x	x	
10. Ceylon	1965	x		41	41		ISIC				x	x
11. Costa Rica	1957	x		19[4/]	17[4/]	x			x[8/]			
12. Cyprus	1957	x		61	61	x					x	x
13. Czechoslovakia	1962	x		96	96						x[7/]	x[7/]

Table 3 (continued)

Country	Categories of final demand				Categories of primary input									
					Compensation of employees									
	Private gross fixed capital formation	Public gross fixed capital formation	Change in Stocks	Exports	Total	Wages & Salaries	Employers contribution to social security	Depreciation	Comm. Taxes	Import Duties	Minus subsidies	Rest of indirect taxes minus subsidies	Operating surplus	Rest of Value Added
	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1. Algeria			x	x		x	x	x			x	x	x[38/]	
2. Argentina		x	x	x										x
3. Australia			x	x[29/]	x					x		x		x
4. Austria	x	x	x	x[30/]		x	x	x			x	x	x	
5. Belgium		x	x	x[30/]		x	x	x				x	x	
6. Bolivia		x	x	x										x
7. Brazil		x		x	x									x
8. Bulgaria		x[7/]	x[7/]	x[7/]		x[7/]						x	x	
9. Canada	x		x	x	x				x		x	x	x[39/]	
10. Ceylon		x	x	x								x		x
11. Costa Rica		x[8/]		x						x				x
12. Cyprus		x	x	x										x
13. Czechoslovakia		x[7/]	x[7/]	x[7/]		x[7/]		x[7/]				x[7/]	x[7/]	

Table 3 (continued)

14.	Denmark	1953	x	x	19	19		SITC		x			
15.	Egypt	1962	x		13	13	x					x	x
16.	Fiji	1967	x	x	4[5/]	15[5/]	x					x[9/]	x
17.	Finland	1965	x	x	66	66	x	ISIC				x	x
18.	France	1962	x	x	78[1/]	78	x					x[10/]	x
19.	Germany, Federal Republic of	1966	x		54	54	x					x[11/]	x[11/]
20.	Greece	1960	x		50	50	x					x	x
21.	Guyana	1959	x		14	14	x					x	x
22.	Hungary	1968	x		83	83	x		x[7/]				
23.	India	1964/65	x		77	77	x					x	x
24.	Iran	1965	x		30	30		ISIC				x	x
25.	Iraq	1963	x		32	32		ISIC				x	x
26.	Ireland	1964	x	x	92	92	x					x	x[12/]
27.	Israel	1968/69	x		30	30	x					x	x
28.	Italy	1967	x		77	77	x			x			
29.	Ivory Coast	1960	x	x	21[1/]	21						x[13/]	x
30.	Jamaica	1958	x		17	17	x				x	x	
31.	Japan	1965	x	x	156	156	x					x[14/]	x
32.	Jordon	1968	x		39	39	x					x	x
33.	Korea, Republic of	1968	x		43	43	x					x[14/]	x
34.	Lebanon	1964	x		14[1,2/]	14	x					x	x
35.	Malawi	1968	x		10	10	x			x			
36.	Malaysia	1960	x		34	34	x			x			
37.	Mali	1958	x		8[1/]	8	x			x			
38.	Malta	1968	x		24	24	x				x	x	x
39.	Mexico	1960	x		45	45	x	ISIC				x	x
40.	Morocco	1958	x		31[1/]	31	x					x	x
41.	Netherlands	1964	x		35	35	x					x	x
42.	New Zealand	1959/60	x		110	110	x	ISIC				x	x
43.	Nigeria	1959/60	x		20	20	x			x			

Table 3 (continued)

14.	Denmark		x[20/]		x	x	x						x			x	x	
15.	Egypt	x		x	x	x	x									x		x
16.	Fiji		x[31/]			x[31/]	x						x[34/]		x	x		x[42/]
17.	Finland		x		x	x	x									x		x
18.	France	x[22/]		x	x[27/]	x							x					x
19.	Germany, Federal Republic of		x		x	x	x				x					x	x	
20.	Greece		x		x	x	x									x		x
21.	Guyana		x			x										x		x
22.	Hungary		x[7/]		x[7/]	x[7/]		x[7/]										x[7/]
23.	India		x		x	x					x							x
24.	Iran		x[20/]			x	x				x					x	x	
25.	Iraq		x		x	x	x									x		x
26.	Ireland		x		x	x[29/]	x				x	x[35/]		x		x[35/]	x	
27.	Israel		x		x	x	x						x[36/]	x[36/]		x		x
28.	Italy		x		x	x		x	x	x			x			x	x	
29.	Ivory Coast	x[23/]		x	x	x	x									x		x
30.	Jamaica		x			x	x									x		x
31.	Japan		x		x	x	x				x					x	x	
32.	Jordan		x		x	x	x						x					x[43/]
33.	Korea, Republic of		x		x	x												x
34.	Lebanon	x		x	x	x												x
35.	Malawi		x		x	x	x									x		x
36.	Malaysia		x		x	x										x		x
37.	Mali		x			x												x
38.	Malta		x			x	x									x		x
39.	Mexico	x		x	x	x	x				x					x	x	
40.	Morocco		x[24/]		x	x	x							x		x		x
41.	Netherlands	x		x	x	x		x	x	x				x		x	x	
42.	New Zealand		x		x	x	x				x					x	x	
43.	Nigeria		x			x												x

Table 3 (continued)

44.	Norway	1964	x	x	36[2/]	36	x					x	x
45.	Pakistan	1960/61	x		30	30	x	ISIC	x[6/]				
46.	Peru	1959	x		8	8	x		x				
47.	Phillippines	1961	x		198	198	x					x	x
48.	Poland	1962	x		144	144	x					x[7/]	x[7/]
49.	Portugal	1959	x		18	18	x					x	x
50.	Senegal	1959	x		18	18	x					x[5/]	x
51.	South Africa	1956/57	x		48	48						x	x
52.	Spain	1962	x		86	86	x					x	x
53.	Sudan	1961/62	x		14	14	x					x	x[16/]
54.	Swedan	1964	x	x	32	32	x	(SITC ISIC)				x	x[12/]
55.	Togo	1958	x	x	8[2/]	10	x					x	x
56.	Trinidad and Tobago	1962	x		13	13		ISIC				x	x
57.	Tunisia	1957	x		21	21	x			x			
58.	Turkey	1963	x		37	37	x	ISIC				x	x
59.	U.S.S.R.	1966	x		110	110	x					x[7/]	x[7/18/]
60.	United Kingdom	1963	x	x	73	73	x					x	x
61.	United States	1963	x	x	367	367	x	ISIC			x	x	x
62.	Yugoslavia	1966	x		98	98	x					x	x
63.	Zaire	1957	x		14	14	x					x[19/]	x
64.	Zambia	1967	x		38	38		ISIC				x	x

Table 3 (continued)

44.	Norway		x		x	x	x			x				x	x	
45.	Pakistan													x		x
46.	Peru				x	x	x			x				x	x[40/]	
47.	Philippines		x		x	x	x			x				x	x	
48.	Poland		x[7/]		x[7/]	x[7/]		x[7/]						x[7/]	x[7/41/]	
49.	Portugal		x		x	x										x
50.	Senegal		x		x	x	x[32/]					x		x		x
51.	South Africa		x		x	x	x							x		x
52.	Spain	x		x	x	x		x	x	x				x[37/]	x	
53.	Sudan		x		x	x								x		x
54.	Sweden		x		x	x	x			x				x	x	
55.	Togo	x		x[25/]	x	x		x	x				x	x		x
56.	Trinidad and Tobago		x		x	x	x			x				x	x	
57.	Tunisia		x		x	x		x	x	x			x	x	x	
58.	Turkey	x		x	x	x								x		x
59.	U.S.S.R.		x[7/26/]		x[7/]	x[7/]		x[7/33/]	x					x[7/]	x[7/44/]	
60.	United Kingdom		x		x	x	x							x		x
61.	United States	x			x	x										x
62.	Yugoslavia		x		x[28/]	x	x			x						x
63.	Zaire		x		x	x	x[32/]			x						x
64.	Zambia		x		x	x	x			x	x		x	x	x	

Table 4. Some Characteristics of 18 Development Planning Models [1]

Reference	Country	Objective Function basic case	Open or Closed Loop	Solution Tech. (if other than linear prog.)	Problem size				Labor substitution possibilities; human capital formation
					No. of time periods	Length of planning (years)	No. of I/O sectors	No. of labor skill classes	
Adelman (1966)	Argentina	Alternatives; 1) maximize discounted GNP; 2) maximize GNP, terminal year; 3) minimize discounted sum of net foreign capital flow	Closed		4	20	9	6	Substitution between educational levels for each labor skill type; human capital formation for all labor skills.
Adelman et al. (1969)	South Korea	No explicit objective function	*Open*	Consistency model, dynamic input-output	7	7	43	1	
Blitzer (1971)	Turkey	Maximize GNP, terminal year	Closed		5	15	8	6	Human capital formation for all labor skills
Bruno et al. (1970)	Israel	Maximize discounted consumption plus value of terminal capital stocks	Open	Static input-output matrix was inverted to reduce the number of rows and columns in the linear prog. matrix	6	16	30	2	
Celasun (1971)	Turkey	Maximize GNP, terminal year	Closed		3	8	13	0	
Clark & Taylor (1972)	Chile	No explicit objective function	Open	Consistency model dynamic input-output. Terminal year output targets obtained through static linear prog. applying a stock flow conversion factor for investment.	10	10	17	8	Partial substitutability between labor types.

Table 4. (continued)

Eckaus & Parikh (1968)	India	Maximize discounted consumption, subject to consumption growth constraints	Open		10	30	11	0	
Gorcux (1973)	Ivory Coast	Maximize discounted utility of consumption from individual commodities, assuming want independence.	Open		5	25	3	3	Import of labor; diminishing marginal productivity of unskilled urban labor in the traditional service sector
Gupta (1971)	India	Maximize discounted consumption.	Open		10	10	4	2	
Johansen (1968)	Norway	No explicit objective function	Open	Consistency model, dynamic input-output	9	27	28	1	Capital labor substitution in all 28 sectors through Cobb-Douglas form of production function.
Keesing & Manne (1973)	Mexico	Maximize consumption subject to gradualist growth constraints.	Open		6	18	15	5	Capital-labor substitution in agri. only; human capital formation for all labor skills

Table 4. (continued)

Kendrick & Taylor (1971)	Korea	Maximize discounted utility of consumption	Open	Conjugate gradient method of optimal control	30	30	4	1	Capital-labor substitution in all 4 sect. through CES form of production func.
Kornai (1969)	Hungary	Alternatives[a] 1) maximize consumption, 2) maximize foreign exchange surplus with a) capitalist or b) socialist countries; 3) minimize gross investment; 4) minimize labor inputs; 5) minimize prime costs.	Open	Multi level programming; an approximation to Dantzig Wolfe decomposition	1	5	491	1	Capital labor substitution through changes in the mix of each item's output from 3 vintages of equipment; old, modernized and new.
Manne & Weiskopf (1970)	India	Maximize consumption, subject to gradualist growth constraints	Open	Preliminary data processing to reduce number of rows and columns in the linear programming matrix	4	8	30	0	
Martens & Pindyck (1973)	Tunisia	Minimize the weighted sum of squares of deviations from a 'nominal' path for each state and control variable.	Closed	Linear quadratic tracking method of optimal control.	15	15	5	1	

[a] In each case, there are predetermined bounds on the macroeconomic variables. These bounds are targets derived from official Hungarian five-year plans, and are based upon traditional planning methods, not upon mathematical programming.

Table 4. (continued)

Murakami etal. (1970)	Japan	Maximize capital stocks, terminal year.	Closed	Composition of terminal capital stocks computed through characteristic vector associated with largest characteristic tool of dynamic Leontief matrix	8	8	10	0	
Ujlaki (1971)	Hungary	Alternatives:[a] 1) maximize discounted consumption; 2) maximize capital stocks, terminal year; 3) maximize discounted foreign exchange surplus.	Open		4	20	20	1	Capital labor substitution through changes in the mix of each item's output from 3 vintages of equipment; old, modernized and new.
Westphal (1971)	Korea	Maximize discounted utility of consumption.	Open	Mixed integer programming	5	10	11	0	

[a] In each case, there are predetermined bounds on the macroeconomic variables. These bounds are targets derived from official Hungarian five-year plans, and are based upon traditional planning methods, not upon mathematical programming.

in the latter the technical structure of the economy is bound to change rapidly, and hence more frequent updating is required.

7. CONCLUDING REMARKS

Input-output tables are based on the assumption of fixed proportion. This assumption is justifiable for a given technology, but in fact technology does change over time. Many studies are being conducted on the stability of input-output coefficients, and on the seriousness of errors due to instability. This instability is considered one of the factors unfavorable to the utilization of input-output models in development planning of some developing countries, where technological changes are rapid.

In spite of these drawbacks, input-output tables are considered one of the best achievements for structuring the economy in the last few decades. In the early days of their introduction, input-output methods were considered as having bridged the gap between the theoretical economists and the working statisticians. They did not only make use of the growing volume of economic statistics, but also stimulated the collection and organization of statistics in a consistent and rational manner.

In developing countries statistics necessary for input-output tables might readily be available in the country but it is dispersed rather than scarce. The adoption of input-output methodology will even spur the collection and organization of statistical data if it is not already available, such as the experience of developed countries. The problem of changing technology can be approached by using updating techniques suitable for developing countries. In summary, what is needed is an adaptation of the technique rather than the preclusion of developing countries from the benefits of input-output methodology.

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CHAPTER III

DEVELOPMENT PLANS OF THE SUDAN

1. INTRODUCTION

Development planning in Sudan, which gained its independence in 1956, can be traced back to the 1940's when it was under British rule [10]. These efforts, however, were more or less in a form of two 5-year development programs for the public sector covering the periods 1946-50 and 1951-55. They were lists of "longer term" investment proposals by the various government departments. These programs were approved under a separate development budget, and no attempt was made to study the economy's resources and the effect of these programs on the whole economy.

Post-independence economic development efforts started in the years 1957-60. In this period an interim "new schemes" program was followed on an annual basis. In this period also the economic features or the structure of the economy was formulated into an input-output table referring to the years 1955/56 [3]; other I/O tables were also available for the years 1961/62 and 1962/63 [9].

The Sudan's 10-year plan of economic development, 1961/62-1970/71, represented the first attempt of the government to formulate and execute a comprehensive development plan. This was followed by a second comprehensive development plan of 5-years, 1970/71-1974/75. However, this 5-year plan was modified by the introduction of the "Interim Action Programme", into a 7-year plan, 1970/71, 1976/77. The most recent economic plan is a 6-year plan, 1977/78-1982/83, which is considered a first phase of a prespective plan extending over eighteen years, 1977/78-1994/95, which is to be implemented in three phases of six years each.

2. THE TEN-YEAR PLAN

As mentioned earlier this had been the first comprehensive plan; under this development plan the government tried to encourage and stimulate the private enterprise as well as establishing its own industrial projects [1].

The objectives of the 10-year plan were:

1. To achieve a substantial increase in real per capita income (5% overall growth rate).
2. Broadening the structure of the economy.
3. Increasing exports, besides import substitution.
4. Improvement in social conditions and services and creation of new employment opportunities (a shift of 800,000 workers from the traditional to modern sector).
5. The maintenance of a relatively stable price level.

A growth model encompassing these objectives was made [6] where aggregates of saving, consumption, imports, exports, and employment were projected. The plan used techniques such as cost-benefit analysis, and input-output tables. The plan was also tested for feasibility and consistency.

The shares of the public and private sectors in the total investment were 60% and 40% respectively. The sectoral distribution of the gross fixed investment is shown in Table 1.

The planned finance of the plan was by domestic savings, 74%, foreign loans, 25%, and from foreign exchange reserves, 1%, [6].

The main structural elements in the Sudanese economy at the beginning of the plan [4] were as follows:

1. A thinly populated country with population growing rapidly at 2.8% annually.
2. The traditional sector producing 50% of the national income while it encompasses about 75% of the population. The sector's growth rate is about 3% annually.

Table 1. Distribution of sectoral investment

SECTORS	LS Million			In %
	Private	Public	Total	of total
*Agriculture including fisheries and forestry	30	90.1	120.1	21%
*Industry including public utilities, building and civil Eng., mining industry	65	41.9	106.9	19
*Transport distribution	32	63.0	95.0	17
*Social services, including housing, health, education administration	60	90.0	150.0	27
*Total expansion investment	187	285.0	472.0	84
*Replacement investment	41.4	52.0	93.4	16
*Total gross fixed investment	228.4	337.0	565.4	100

Source: Ten-Year Plan of Economic and Social Development 1961/62-1970/71. Explanatory Memorandum on 1965/66 Development Budgets, Ministry of Economics and Finance, Khartoum, 1965, p. 5.

3. The modern sector produces agricultural products for export. Its annual rate of growth is about 6.5%; it has also started to diversify its products.
4. A small but rapidly growing industrial sector, constituting 2% of the gross national product, and a large transport sector.
5. The budget revenue highly dependent upon taxes on foreign trade (55%).
6. The public sector participating by about 60% of the investment in development which has produced an annual growth rate of about 5% in the recent past.

Table 2 shows the expected annual growth of population and per capita income in each of the two major sectors, traditional and modern. It should be noted that the increase in productivity in the traditional sector is in part due to an indirect effect of growth in the modern sector, i.e., the migration of 800,000 from the traditional to the modern sector [4]. The increase in gross domestic product can be split up into the three factors which lead to this increase, Table 3. Thus 50% of the increase in GDP (53 + 60) is due to population growth, 35% (51 + 29) is due to increase in productivity, and 15% due to structural effect-the expansion of the modern sector [4]. Appendix I shows the financial aspects of the 10-Year Plan.

Gusten's [4] study concentrates on checking the underlying assumptions of the plan and whether the targets set in the plan are pitched too high or are feasible. As an example he argues that the movement from the traditional to the modern sector will lead to lower productivity in this sector contrary to the plan as there will be real migration, and usually those who migrate are the most vigorous and enterprising men. To solve for this expected loss in productivity he suggested the increasing of direct measures like extension service advisory facilities, insect and pest control, etc.

He also computationally shows that the targets set for the plan (i.e., a 5% growth rate of GDP, 3.3% for traditional, and 6.7% for modern sector) require

Table 2. Growth of Per Capita Income and Population

Year		Modern Sector		Traditional Sector		Total Plan	
		Per Capita in LS	Population in Millions	Per Capita in LS	Population in Millions	Per Capita in LS	Population in Millions
1960/61		53	3.2	21.5	8.7	30	11.9
1970/71	Natural growth of population		4.2		11.5		15.7
	Migration		+ .8		- .8		0
		65	5.0	24	10.7	37	15.7
Annual Growth Rate		2.1%	4.5%	1.2%	2.1%	2.2%	2.8%

Table 3. Sources of the increase in GDP (in Million LS)

Sector	Population	Productivity		Total
	Extensive Growth	Intensive Growth	Structural Effect	
Modern	53	51	33	137
Traditional	60	29	-	89
Total	113	80	33	226
%	50%	35%	15%	100%

a 13.4% annual growth rate for the secondary sector (industry, mining, building, and public utilities), which is a very high rate at this state of development, especially with 67% of investment in industry left to the private sector. Reducing the growth rate of GDP to 4.5% he arrives at an annual growth of only 10% for the secondary sector.

Wynn [10] reviewed the framework and execution of the plan in the first six years. He agrees with Gusten that the target growth rates are ambitious and that is why by the end of the six year period the actual growth rate of the modern sector was about 6% per annum instead of 6.7%, real income improvement was about 4.5% per annum (allowing for 1.5% annual increase in factor prices), which was to some extent less than the planned income growth of 6.1% per annum for the modern sector. The Incremental Capitol Output Ratio (ICOR) for the modern sector for the first five years was about 5:1 while the plan assumed a value of 4:1 which is the 1956-60 actual ratio.

The evaluation of the implementation and performance of the plan is discussed also in [5,6,7], which can be summarized in the following:

1. Investment was above the plan level, especially in the first five years. There was deviation from the sectoral allocation of investment. Management of the plan suffered from the lack of managerial skills. The multiplicity of government bureaus and departments involved made it difficult to coordinate planning, and to control and make policy decision. There was deviation from the plan by including additional investment projects and excessive government expenditure, failure to raise enough domestic savings, and lack of sufficient foreign finance.
2. Some of the above problems were met with immediate corrective actions, especially the financial side of the plan which had led to financial disequilibrium in the economy. The government consequently expanded the money supply which actually exceeded the overall growth rate of the economy. However, it did not lead to a rapid inflation due to the

fact that there was increased demand for money for transactions and also because it is used as a medium of savings in the traditional sector of the economy. Other corrective actions included imposing higher import duties on consumer goods, rescheduling of investment, tax increase, etc.

3. Some objectives were not fully met: the economy's rate of growth was less than the target; the financial equilibrium was not maintained; no big improvement in per capita income was felt; and broadening of the industrial structure was not very successful,as in some situations plant construction was carried on without provision for raw material supplies; infrastructure and industrial investment were undertaken in the absence of forward and backward linkages; and there was no provision for the utilization of the by-products. However, the gains achieved in the manufacturing sector led to the broadening of the economic base and diversified the domestic economy.
4. The broadening of the agricultural sector was more successfully fulfilled where its expansion and new investments resulted in significant gains in output, cultivated area, and application of modern agricultural methods. The agricultural output had consequently increased more rapidly than population, and at the same time new products were introduced on a large-scale basis.
5. Another contributing factor in the failure to attain the objectives, besides implementation drawbacks, may have been the civil war in south Sudan at that time. Also, the plan objectives might have been set on an incorrect assessment of the potential performance of the economy (ICOR of 2.5 for the plan). However, this had been in fact the country's first experience of such a comprehensive plan.

3. THE FIVE-YEAR PLAN

Before the end of the 10-year plan period and due to the deviation from the plan, a new plan was conceived to cover the period 1969-73; the plan was announced in early 1969 but was cancelled following the military coup in May, 1969. A reformulated 5-year plan was put into effect by the end of 1970.

The objective of the revised plan were [5,6]:

1. To attain a 7.6% annual growth rate in gross domestic product (from LS 567 million to LS 816 million).
2. To increase domestic product per capita by 5.5% annually.
3. To raise the agricultural production, livestock production, and industrial production by 60.8%, 75.5%, and 57.4% respectively.
4. To achieve a surplus in the current account of the balance of payment.
5. To develop urban and rural power networks so as to provide all cities and villages with electricity and drinking water.
6. To promote the prosperity of the people through raising productivity, achieving full employment, and increasing the technical capability of the employees.

The plan, however, was subject to some revision. Due to the political instability in the early two years the execution was not completely in line with the plan, although actual investment in the first year was 69% but dropped afterwards [7]; the sectoral distribution of investment is shown in Table 4. This situation led to the draft of "The Interim Action Program" in 1973 which lists some projects and long-term aspirations; it was adopted by the end of 1973 for the period 1973-1977, even before its total investment requirement was determined, programmed or phased out. The broad objectives of the "Interim Action Program" [5] were:

1. To achieve self-sufficiency in essential goods and services.
2. To achieve better balance between production and consumption.
3. To minimize the burden on the economy of government budgetary expenses.

Table 4. Sectoral distribution of investment (LS Million)

SECTOR	Initial Plan				Revised Plan			
	Private	Public	Total	%	Private	Public	Total	%
*Agriculture	26.5	80.0	106.5	27.6	26.5	124.5	151.0	25
*Industrial	24.5	36.4	60.4	15.7	24.0	67.8	91.2	15.1
*Transport and communications	31.0	29.6	60.6	15.7	31.0	129.3	160.2	20.6
*Power	--	12.8	12.8	3.4	--	18.6	18.6	3.1
*Services and construction	88.5	44.1	132.6	34.4	88.5	72.2	160.7	26.7
*Technical assistance	--	9.8	9.8	2.5	--	11.9	11.9	2
*General reserves and southern region	--	2.3	2.3	0.7	--	9.2	9.2	1.5
*Total	170.0	215.0	385.0	100.0	170.0	432.9	602.9	100.0

Source: Economic Survey 1973, National Planning Commission, Khartoum, August, 1979, p. 111.

The introduction of this "Interim Action Programme" (IAP) was also complemented with a new financing technique-the "Umbrella Budgeting". To explain this [2 p.6]:

> "....The major objective of the Umbrella System was to ensure flexibility so that execution of any development project was not hampered for want of funds. It was assumed that the major factor limiting the actual size of investment was the executive capacity of different Ministries and government units and not the lack of financial resources. The allocations of units which showed poor performance were to be transferred, during the financial year, to better performers. In this way, the government sought to prevent the locking up of funds and to provide the budget with flexibility to achieve the highest possible utilization of financial resources. ...."

The plan's initial formulation was to achieve a high rate of growth by relying on vertical development or increase productivity to a great extent by the utilization of idle capacities in the economic sectors. It was also formulated so as to minimize foreign loans and depend more on local resources. One of its outstanding policies was to rely on projects with quick returns so as to generate more investment in the future. Consequently the incremental capital output ratio (ICOR) is very low, 1·55.

During and following the formulation of the initial plan and its related revisions, however, the political atmosphere was not favorable to the plan, and it lacked real understanding, acceptance and coordination. Thus a genuine evaluation of the framework and execution of the plan is difficult.

By the third year of the plan an alternative was sought, and instead of a new plan it was complemented by the IAP. The IAP, however, was put into action even before its scope or implications were fully studied. Following this step the 5-year plan seems to have been dissolved, and consequently it would be very

hard to evaluate the implementation of the true 5-year plan; also the introduction of IAP led to the extension of the plan period from five to seven years. According to the Ministry of National Planning [2], neither the 5-year nor the 7-year plan performance can be accurately assessed due to lack of reliable and current data; however, a tentative assessment is as follows:

1. Annual growth rate of GDP is between 4 and 5% in real terms (17% in monetary terms) instead of 7.6%.
2. Actual investment was stationary in the first three years and started to shoot up in the last two years.
3. The annual development budget was in no way according to the plan.
4. Instead of a 20 million surplus in the balance of trade, there was a deficit of 122.2 million.

The reasons for the underattainment of the target growth rate of GNP were [2 p. 1]:

1. Soaring energy prices
2. International inflation
3. Low investment performance both in the private and public sectors.

The increase in investment in the last two years was due to the escalation of project costs, changes in the scope of projects, and inclusion of new projects from the IPA. The consequences of the unique policy of "Umbrella System of Budgeting" (USB) for the last two years was evaluated by the Ministry of National Planning as follows [2 p. 7]:

> "... So long as the spending capacity of the Ministries and other government units was rather limited, high budget allocations under the Umbrella System did not pose any major problems. But development expenditure rose to Ls. 122.7 million in 1974/75 from Ls. 44.7 million in 1973/74, and Ls. 29.6 million in 1972/73 making it increasingly difficult for the government to provide adequate funds for development. In the absence of any

> savings by the public sector as a whole, internal liquidity posed a serious problem. Umbrella budgeting came under serious criticism in 1974/75."

As can be seen there is some contradiction as to whether USB posed any problems and no mention of the effects of the obligations incurred by USB over the succeeding years as many projects were consequently signed under this unbounded system.

Another effect of USB finance can be related to the sharp price increases in the last two years, as can be seen from Table 5, due to the large expansion of money supply in this period. Table 6 shows the actual to the planned development expenditure, while Table 7 shows the actual to the projected USB and the percentage deviations.

The plan expectation was far away from the actual as can be seen in Table 8; the public sector's saving was zero compared to a projected LS 105 million, while deficit finance contributed to 68% of the public sector's development expenditure.

Table 5. Prices and Cost of Living Indices

Year	Wholesale Price Index	Consumer Price Index	Base year 1970 - 100 Cost of Living Index (Calendar Years) Low Salaried	High Salaried
1969/70	98	109.4	106.7	105.5
1970/71	99	106.8	108.2	106.8
1971/72	101	112.8	120.9	115.5
1972/73	114	127.9	141.6	133.7
1973/74	140	154.9	178.6	165.9
1974/75	170	191.6	221.4	200.9

Source: Department of Statistics.

Table 6. Planned vs. Actual Expenditure (LS million)

	1970/71	1971/72	1972/73	1973/74	1974/75
Planned development expenditure	36.0	41.5	44.5	48.0	45.0
Actual expenditure (excluding technical assistance)	25.0	28.0	29.6	44.7	122.7
Rate of execution (%)	69	67	67	93	273

Source: [2]

Table 7. USB vs Actual Expenditure (LS Million)

	1970/71	1971/72	1972/73	1973/74	1974/75
Budget estimate	37.2	66.0	65.6	100.0	194.3
Actual expenditure	25.0	28.0	29.6	44.7	122.7
Rate of execution (%)	67	42	45	45	63

Source: [2]

Table 8. Planned vs Actual Sources of Finance for the Public Sector (LS Million)

	Plan (1970-75)	% of Total	Actual (1970-75)	% of Total
Total development expenditure	215.0	100.0	250.0	100
Source of finance:				
1) External resources	110.0	51	80.3	32
2) Public sector savings	105.0	49	0.0	0.0
3) Deficit Finance	0.0	0.0	169.7	68

Source: [2]

4. THE SIX-YEAR PLAN

This is the latest plan, and its execution has entered the third year. The preparation of this plan involved a wide participation of experts from the universities, higher educational institutes, research centers, ministries, departments, public corporations and private sector in addition to a number of international experts [2].

The 6-year plan is the first phase of an 18-year perspective plan (1977/78-1994/95). The general objectives of the perspective plan are to transfer the economy from the take-off to the self-sustained growth stage and achieve a regionally balanced, self-reliant, and accelerated development so as to triple the real income per capita by 1995 with equitable distribution.

The overall goals and quantified targets of the perspective plan are:

1. To attain 8.5% average overall growth rate of GDP, and a 6% per annum increase in income per capita in real terms.
2. To increase the nonagricultural share in GDP from 60% to 70% by 1995.
3. To increase the basic services at an annual rate between 9 and 10%.
4. To attain a proper regional and structural distribution, that is to broaden the structure of the economy and achieve diversification of output and export of final goods besides an increase in the domestic production of inputs and intermediate goods.
5. To achieve a gradual improvement in the balance of payments and the mobilization of savings so as to close the gap between investment and savings, and the import-export gap.
6. To mobilize the people and institutions in order to insure their greatest participation in the development process.

The 6-year plan (1977/78-1982/83) aims to achieve an accelerated and balanced growth in the economy by combining development with social equity. The plan objectives are [2]:

1. To attain an annual growth rate of 7·5% in constant prices, with a sub-

stantial increase in per capita income in real terms through the development of both modern and traditional sectors.

2. To conserve the country's natural resources.
3. To develop and modernize the traditional agricultural sector.
4. To increase the productivity of all the sectors of the economy and improve the rate of implementation.
5. To expand the productive employment opportunities and limit unemployment, with the ultimate goal of eradicating it.
6. To develop industry as a complementary sector to agriculture, with first priorities given to agro-industries and import-substitution. Additional investment opportunities would be tapped, particularly in the field of mineral prospecting in order to broaden the base of the economy.
7. To attain self-sufficiency in certain food and other agricultural commodities and inputs.
8. To consolidate and expand the basic infrastructure, especially in the field of transport, communications, power resources, marketing and storage facilities.
9. To improve the balance of payments through expansion of exports and production of import substitutes.
10. To encourage both the foreign and local private sector in order that it can play its role fully.
11. To develop the cooperative movement.
12. To provide more social services and upgrade their standards.
13. To pay more attention to rural development.
14. To increase and mobilize public and private savings.
15. To work for the development of the administration by raising the standards of organizational and administrative cadres.
16. To base central development planning firmly on regional planning.

4.1 Macro-Economic Projections and Structure:

The plan calls for more emphasis on the provision of infrastructure. Manufacturing is assumed to grow at a high rate of 9.5% annually while agriculture will grow at 6.5% annually. Table 9 shows different sectoral growth rates and the percentage share of each sector in GDP.

The structure of demand must conform to the changes in output resulting from the planned sectoral growth rates. Table 10 shows the planned structure of demand, where government and private consumption are to grow at lower rates than that of GDP.

Investment requirements are estimated in the light of the target growth rate and by an estimate of the incremental capital output ratio (ICOR) equal to 3. The ratio of gross investment to GDP is projected to rise from 17.5% in the base year to 22.5% in 1982/83. Row six of Table 11 shows gross investment for each year of the plan. The projected gross investment of LS 2910 million for the plan period consists of LS 2670 million for fixed capital investment and a LS 240 million increase in stocks.

Exports, as can be seen from Table 11, are projected to increase at the rate of 11% annually at constant prices, while imports are projected to grow at a rate of 10% per annum. Import substitution is expected to be high so that the expansion in imports will be mainly due to import of capital goods.

Resource balances, Table 11, indicate that LS 1327 millions of external capital are needed.

Although the policy is to encourage the private sector to play a great role in the development plan, the public sector still has a dominant share in investment as it is essential to create the basic infrastructure to pave the way for future development. Table 12 shows a comparison of the shares of both sectors in the three development plans since 1960.

The allocation of the public sector's investment in the various sectors of the economy is based on past experience, existing commitments, resource constraints

Table 9. Planned Growth Rates and Sectoral Changes (%)

Sectors	1976/77 %	1982/83 %	Annual Growth Rate %
Agriculture	39	37	6.5
Manufacturing & Mining	9	10	9.5
Electricity & Water	1	1	8.0
Construction	4	5	9.0
Transportation	6	6	7.5
Commerce, Finance & Real Estates	24	24	8.0
Government & other services	11	11	7.5
GDP at MP	100	100	7.5

Source: [2]

Table 10. Planned Structure of Demand

Expenditure on GDP	1976/77 % of GDP	1982/83 % of GDP	Growth Rate %
Govt. final consumption	14	13	6.5
Private consumption	77.5	74	6.7
Gross capital formation	17.5	22.5	12.1
Exports of goods & services	12	14	11.0
Imports of goods & services	21	24	10.0
Total expenditure	100	100	7.5
Gross domestic savings	8.5	13	
Foreign debt servicing	3	3	
Gross capital inflow	12	12.5	

Source: [2].

Table 11. Resources Balance in Millon LS (at 1976/77 Constant Prices)

	Preplan years								
	1974/75 (Actual at 1975 Constant Prices)	1976/77 (Provisional)	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1977/78 1982/83 Total
Availability of resources									
GDP at M. P.	1511	1822	1959	2106	2263	2433	2616	2812	14189
Import of goods & services	316	378	416	459	503	553	609	670	3210
Export of goods & services	183	214	238	264	293	325	361	400	1881
Import surplus	133	164	178	195	210	228	248	270	1329
Total availability	1644	1986	2137	2299	2473	2661	2864	3082	15516
Use of resources									
Gross investment	265	319	358	401	449	504	565	633	2910
Total consumption	1379	1667	1779	1898	2024	2157	2299	2449	12606
(a) Govt. consumption	208	255	272	289	308	328	349	372	1918
(b) Private consumption	1171	1412	1507	1609	1716	1829	1950	2077	10688

Source: [2]

Table 12. Shares of Public and Private Sectors in Total Investment (LS Million)

	10-Year Plan (1960-70)		5-Year Plan (1970-75)		6-Year Plan (1977-83)	
	Amount	%	Amount	%	Amount	%
Public sector	337	60	215	56	1570	59
Private sector	228	40	170	44	1100	41
Total	565	100	385	100	2670	100

Source: [2]

Table 13. Investment Sources of Finance (LS Million)

	Public Sector		Private Sector(a)		Total Investment	
	Amount	% of Total	Amount	% of Total	Amount	% of Total
TOTAL Gross Investment	1,570	59	1,100	41	2,670	100
Financed by:						
I. Domestic Resources	735	28	550	20	1,285	48
(a) Public Savings	450	17	--	--	450	17
(b) Private Savings	--	--	550	20	550	20
(c) Deficit Financing	285	11	--	--	285	11
II. External Resources	835	31	550	20	1,385	52

Source: [2]

investment ambitions of various sectors, and the overall development strategy.

The domestic financing of the plan is from three sources: public savings, private savings, and deficit finance. The projected share of each of these three resources and the external resources required for the plan period are shown in Table 13. The external resources constitute 52% of the planned fixed investment while deficit finance constitutes 11%. With a growth rate of total consumption not more than 6.6% a year domestic savings are expected to rise from 8.5% of the GDP in the base year to 13% in 1982/83. Concerning deficit finance the plan calls for some limits [2 p.61]:

> ".... The annual amounts of deficit finance would have to be determined in the light of emergent inflationary trends provided that the amount will not exceed LS. 285 million in real terms during the plan period. In current prices, the annual amount would be limited to 18% of public investment or 63% of public savings, which ever amount is the less."

The balance of payment position as envisaged in the plan period is shown in Table 14, where the projections of imports and exports are made at constant prices. The relative share of consumer import goods is expected to decline as import substitutes for basic commodities by local production is attained.

The plan is expected to provide about 1.424 million jobs, of which 1.369 are for the new entrants in the labour market and those who are presently unemployed, while .065 million jobs are to absorb portions of those performing jobs which can be categorized as disguised unemployment.

Table 14. Consolidated Balance of Payments (in Constant 1976/77 Prices--in LS Million).

The Current Account	1976/77 (Prov.)	77/78	78/79	79/80	80/81	81/82	82/83	Total (77/78-82/83)
Visible Trade	-152	-165	-180	-196	-213	-232	-251	-1237
Total Exports	180	200	222	246	273	303	337	1581
Total Imports	332	365	402	442	486	535	588	2818
Invisible Trade	- 32	- 34	- 35	- 37	- 39	- 41	- 46	- 232
Receipts	- 34	- 38	- 42	- 47	- 52	- 58	- 63	- 300
Payments	66	72	77	84	91	99	109	532
(Interest)	(20)	(21)	(22)	(23)	(24)	(25)	(27)	(142)
Balance of Trade	-184	-199	-215	-233	-252	-273	-297	-1469
The Capital Account								
Repayments	40	40	44	47	47	53	57	288
Balance of Payments (Gross Capital inflow required)	-224	-239	-259	-280	-299	-326	-354	-1757
Net Inflow of External Resources (Gross inflow minus debt servicing)	164	178	193	210	228	248	270	1327

Source: [2]

5. DEVELOPMENT PLANNING: PROBLEMS AND REALIZATION

The most noticeable trend in the first two plans, the 10-Year and the 5-Year, is that neither plan has been carried to the end, as can be seen from Figure 1. The idea of discontinuing the 10-Year Plan and formulating a new plan emerged at the sixth year of the plan, while for the second plan the IAP was introduced in its third year. By tracing the political changes which took place since independence, Figure 1, some explanation may be found to this trend; i.e., plans are more or less politically inspired.

Another common characteristic for the three plans is that the state usually has the highest proportion of investment as can be seen in Table 15. Augoda [1] sees the state as so much involved in the economic activity that the people look to the state for great improvement, and consequently excessive political promises led to overly ambitious development plans. The overly engagement led to an overburdened government machinery characterized by a shortage of well-trained civil servants and weakly disciplined government employees. There is a lack of coordination between different units and an overlapping of responsibilities, overstaffing and overprotection of civil servants, the performance of the state run economic activities is very poor, the management of the economy has been weakly administered with no check on growth of money supply and no control over wage increases.

There is also a continuing deviation from the plan by excessive expenditures and inclusion of unplanned projects.

The planning exercise does not seem to be founded on a complete and real assessment of the economy, and except for the first plan, no economic census prior to the plan was performed. The 10-Year Plan was tested for its consistancy and feasibility with respect to the targets set using techniques such as cost-benefit analysis, input-output table, etc. The other two succeeding plans did not follow the same procedure in their formulation. The 6-Year Plan was even

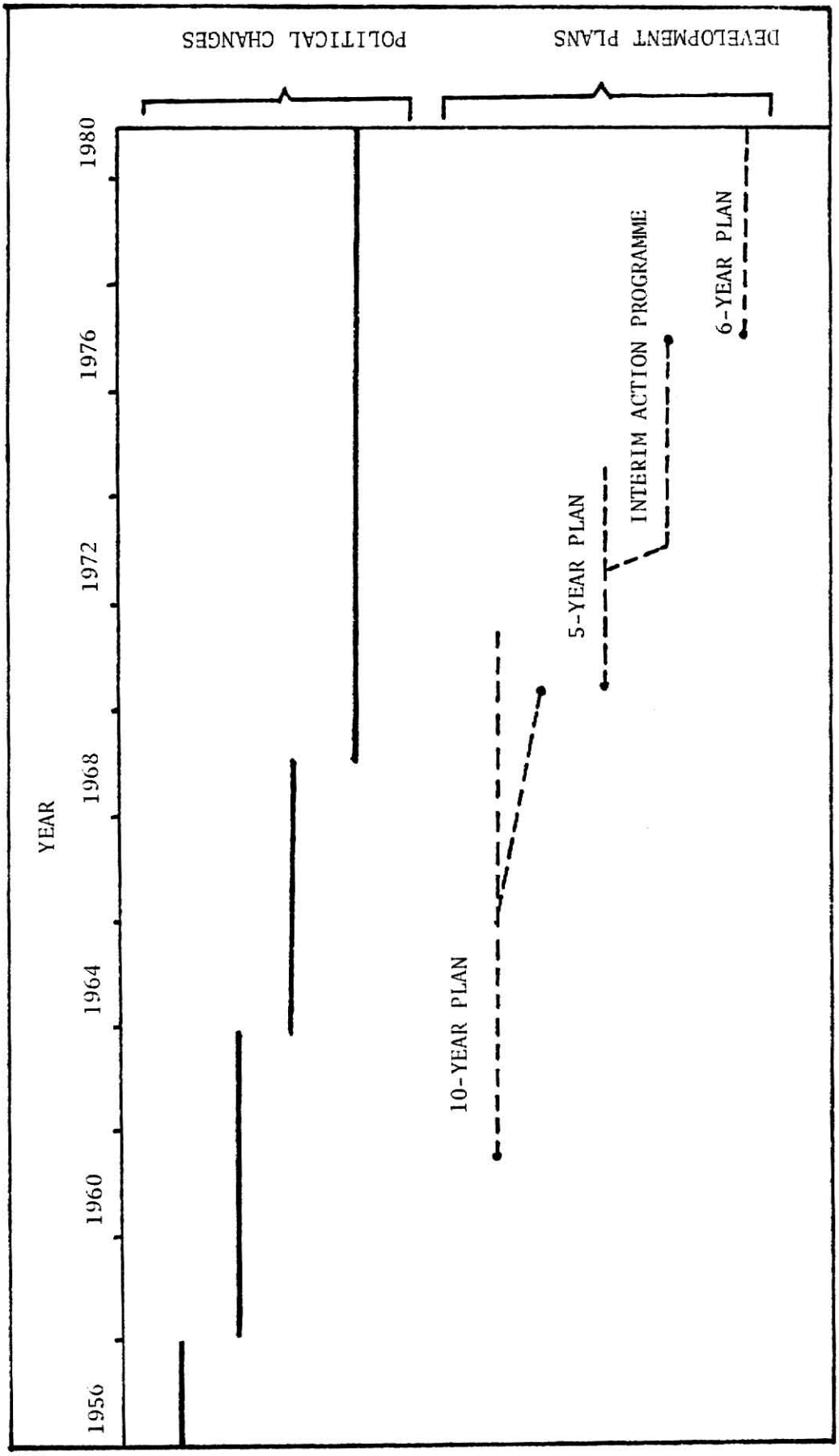

Figure 1. Planning and political changes

Table 15. Some Assumptions and Projections for Plans

	10-Year Plan	5-Year Plan	6-Year Plan
Annual growth:exports (%)	4.7	11.8	11
Annual growth:imports (%)	2	9.4	10
Annual growth:public consumption (%)	6.2		6.5
Domestic sources of finance(%)	73.5	71.4	48.1
Public savings (%)	38.8	27.3	16.8
Private savings (%)	34.7	44.1	20.6
Deficit finance (%)	0.0	0.0	10.7
External sources of finance(%)	26.4	28.6	51.9
TOTAL (%)	100	100	100
Public share of investment(%)	60	56	59
Private share of investment(%)	40	44	41
Capitol-Output Ratio	2.5	1.55	3

prepared before the final national income accounts for the three years preceding the plan were made.

A simple comparison of some of the quantifiable targets for the three plans is shown in Table 16. As can be seen, the second and third plan targets are set very high, and due to the lack of data, no proper evaluation of the actual attainment can be made. However, the 5-Year Plan annual rate of economic growth is roughly estimated [2] to be between 4-5% in real terms or 17% in monetary terms.

The different assumptions and projections for the plans can be seen in Table 15. A noticeable low figure for capital-output ratio, 1.55, was assumed for the second plan while a figure of 3 is assumed for the third plan although it involves more investment in infrastructure. The comparison of actual to planned could only be made in the sources of finance for the first and second plans as in Tables 17 and 18. In the 10-Year Plan no deficit finance was forecasted, but for just the last five years of the plan, deficit finance accounted for about 35% of the total finance for this period, while for the 5-Year Plan, and contrary to expectations, the public saving was zero at the same time deficit finance amounted to 68% of total investment instead of zero.

To Lee [5] the shortfalls to achieve development plans objectives would imply that goal formulation was very unscientific. He points to four types of constraints affecting development in the past three decades. The first is the investment climate which determined the responsiveness of the government to private foreign investment. The second is the availability of infrastructure like roads, other means of transport, electric power, etc. The third is the absorptive capacity which reflects the ability of the local economy to productively utilize new additions to the capital stock. The fourth constraint is the availability of foreign exchange. Table 19 shows how the relative importance of these constraints varied in the last three decades; according to this evaluation the present development plan will face the severe problem

Table 16. Targets Set for the Plans

Objective	10-Year (Planned)	5-Year (Planned)	6-Year (Planned)
Annual growth rate for GDP (%)	5	7.6	7.5
Employment (number)	800,000	950,000	1,434,000
Deficit finance (LS million)	0.0	0.0	285
Annual growth rate of private consumption (%)	4.8		6.7

Table 17. Sources of Finance Expectations (LS Million)

Sources	10-Year Plan Amount	%	5-Year Plan Amount	%	6-Year Plan Amount	%
Domestic Sources	416	73.6	275	71.4	1285	48.1
Private sector	196	34.7	170	44.1	550	20.6
Public sector	220	38.9	105	27.3	450	16.8
Deficit finance	0.0	0.0	0.0	0.0	285	10.7
External sources	149	26.4	110	28.6	1385	51.9
Total	565	100	385	100	2670	100

Table 18 Actual Sources of Finance for Public Sector (LS Million)

Sources	Last Five Years of 10-Year Plan Amount	%	5-Year Plan Amount	%
Public savings	17	12.3	0.0	0.0
Deficit finance	49	35.5	170	68
External sources	72	52.2	80	32
Total	138	100	250	100

Table 19 Fluctuation of Investment Constraints in Sudan 1956-80

Type of Investment Constraint	1956-60	1961-65	1966-70	1971-75	1976-80
Investment climate	4	4	1	1-4	nil
Infrastructure	1	1	3	2-1	1
Absorptive capacity	3	2	4	4-2	2
Foreign exchange	2	3	2	3-4	nil

Note: Number 1-4 indicate ordinal ranking of constraint.
No. 1 indicates most severe constraint, and
No. 4 indicates least severe constraint.

Source: [5]

of infrastructure and the absorptive capacity limitations.

In spite of the lack of information about the performance of the present 6-Year Plan, some preliminary indications show that it will face the same problems as the previous plans, especially as it is incorporating some of the burdens left over from the second plan, particularly those generated by the IAP and its complement the USB. In regard to the mechanism of individual project inclusion in the development plans in the last decade, it has been noted that acceptance of some projects originates in the higher political levels without being studied in detail for feasibility and implications, and scheduled and fitted into the overall plan.

The third plan, as can be seen, depends from the start on deficit finance. The experience, however, of some developing countries with inflationary-financed development plans is not a good one [8]. Due to the inadequacy of savings and the difficulty of channeling them into productive investments, governments of some of the developing countries (Brazil and Argentina as examples) have relied on deficit finance so as to raise the level of investment in the modern sector. The rationale is that deficit-financial inflation itself can lead to an increase in investment: first, by inducing more investment due to the increased profits and higher return on private investment; second, because of low interest rates on borrowed capital; and third, inflation is believed to create an indirect mechanism of transferring real income from non-savers to the saving-groups who are more potential investors. However, some of the studies conducted in some developing countries did not prove that inflation has contributed to the flow of saving [8]. The Brazilian experience [8] has shown that inflationary finance has social costs: the gains from such growth tend to be very unevenly distributed; it leads to the expansion of capital-intensive rather than labor-intensive industries; and it can create undesirable patterns of demand which consequently reinforce the existing dualism. Deficit financing reduces the

level of voluntary savings as people bid up prices of durable consumer goods. Investment may be distorted by the building of luxury housing and the stock of inventories to guard against further inflation. Finally, inflation tends to feed upon itself; i.e., more budget deficits, wage hikes, and frequent devaluations, all leading to more inflation. Although inflationary finance may sometimes contribute to high rates of industrial growth, it frequently reaches this at the expense of more unemployment due to capital-intensive industry and rural urban migration, worsening the distribution of personal income, and reinforcing dualistic tendencies [8].

6. CONCLUDING REMARKS

In this chapter three development plans have been examined separately and as a group with respect to their formulation and implementation. The diagnosis of the three plans indicates that they share a number of characteristics. First, none of the expired plans was carried to the end, and deviations from what was actually planned were excessive. Their formulation was not preceded by complete information and data about the structure of the economy; the targets were set unrealistically high; there was misuse of some policy variables; and finally, the public sector had the biggest share in investments.

The problems of economic growth and policies for Sudan need to be approached from two angles, the political and the planning process itself. However, this study is oriented towards the planning process rather than the political-economic side.

Generally, the planning process in Sudan suffered from the lack of a qualified organizational body or institution for a long period. The first plan was prepared mainly by expatriates, while the second by Russian experts. Little efforts were made to improve the basic statistical and economic information, and the plans seem to suffer from lack of a thorough understanding of the economy's resources and problems. Thus the planning process has become a political tool where the main objective is to support the aspirations of politicians and create a symbol of political change to attract public approval, rather than to foster continuous growth and development on a well founded scientific basis. Also, much is spent on aggregates of a plan while little time and effort are spend on the sectors or projects; the planning process is not seen as a continuous excercise in implementation and evaluation-feedbacks.

If efforts were continued since 1956 to improve the input-output table, the development plans of Sudan would have been on better bases today. The

representation of Sudan's economy with a mathematical model would be of great help in understanding the structure of the economy and policy making, especially if other noneconomic and nonquantifiable factors are incorporated in such a model so as to follow and test the behavior of the system under variable assumptions.

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APPENDIX

The Sudan ten-year plan (1961/62-1970/71)

	61/62	62/63	63/64	64/65	65/66	66/67	67/68	68/69	69/70	70/71	Totals
Financing of Gross Fixed Investment:					in SL million						
1. Central Budget	17.3	21.7	13.9	13.3	12.4	11.9	12.6	13.6	14.4	15.7	146.8
2. Govt. Entities	-1.2	4.3	6.8	7.2	7.7	8.4	9.0	9.7	10.2	10.8	72.9
3. Private Savings	9.1	15.5	14.6	16.2	18.0	20.1	22.8	24.6	26.6	28.7	196.2
4. External Sources	23.1	19.2	18.6	16.3	14.4	12.6	12.2	11.6	11.2	10.3	149.5
5. Gross Fixed Investment	48.3	60.7	53.9	53.0	52.5	53.0	56.6	59.5	62.4	65.5	565.4
					in per cents						
Central Budget	36	35	26	25	23	22	22	23	23	24	
Govt. Entities	-3	7	13	14	15	16	16	16	16	16	
Private Savings	19	26	27	30	34	38	40	41	43	44	
External Sources	48	32	34	31	28	24	22	20	18	16	
Totals	100	100	100	100	100	100	100	100	100	100	
Imports:					in SL million						
6. Investment Goods	27.3	35.2	31.3	28.1	26.3	26.5	28.3	28.0	29.3	30.8	291.1
7. Raw Materials & Fuels 8. Consumer Goods	57.2	60.9	63.4	67.2	71.3	75.6	80.9	86.8	93.4	100.3	757.0
9. ./. Import Substitution	-0.7	-4.1	-8.6	-9.9	-13.1	-16.8	-19.9	-22.3	-26.5	-30.9	-152.8
10. Total Imports	83.8	92.0	86.1	85.4	84.5	85.3	89.3	92.5	96.2	100.2	895.3
11. Total Exports	67.6	77.3	73.0	75.6	77.4	80.9	86.0	91.1	96.1	101.8	826.8
12. Balance of Goods	-16.2	-14.7	-13.1	-9.8	-7.1	-4.4	-3.1	-1.4	-0.1	+1.6	-68.5
13. Balance of Services	-6.9	-4.5	-5.5	-6.5	-7.3	-8.2	-8.9	-10.2	-11.1	-11.9	-81.0
14. Balance of Current Accounts (= Net Capital Inflow)	-23.1	-19.2	-18.6	-16.3	-14.4	-12.6	-12.2	-11.6	-11.2	-10.3	-149.5

Source: The Ten Year Plan of Social and Economic Development 1961/62 to 1970/71, pp. 47, 49, 52, 68 and 70.

CHAPTER IV

INPUT-OUTPUT ECONOMIC MODEL OF SUDAN

1. INTRODUCTION

Input-output tables for Sudan were developed as early as 1955/56 [5, p.11] by Harvie and Kleve from a census of the economy at that time. Other input-output tables were also available for the years 1961/62 and 1962/63 [23]. In spite of this, one can hardly find reference to the utilization of these input-output tables in development plans of Sudan except possibly for the first one, the ten-year plan.

In Section 2 of this chapter a brief survey of the economic models for Sudan will be presented. Section 3 is a detailed presentation of the RAS method for updating input-output tables. In Section 4 a new input-output table is heuristically developed for Sudan in order to utilize it in the following chapter. The methodology consists of reconstruction, updating, then validating the 1962/63 input-output table of Sudan. Real data of Sudan is used in this procedure. Finally, in Section 5 conclusions and suggestions for future extensions are presented.

2. ECONOMIC MODELS OF SUDAN: A SURVEY

2.1 Input-Output Models

As mentioned, the first input-output table for Sudan was constructed as early as 1955/56 [5]. In that table the economy is aggregated into fourteen sectors as can be seen in Appendix I. Of the 196 cells in the production side of the table only 40 cells (about 20%) contain entries of both domestic production and imported raw materials and consumer goods. The demand side is of six sectors: export, government, nongovernment education, households, capital, and stocks. It seems that no other tables, or even updates of these tables, have been constructed for the economy, although the ADAR report referred to a 6 x 6 input-output model [1, p. 70].

2.2 Econometric Models

The most recent macro-economic model of Sudan is the econometric model developed by Marzouk [16] for the ADAR study [1]. It consists of 62 variables, 20 exogenous and 42 endogenous; of the 42 equations of the model,21 are stochastic and 21 are identities and definitional equations. The economy has been divided into five aggregate sectors: primary activities, mining and industry, infrastructure, commerce and finance, and transport sector. The model parameters are estimated from a 15-year sample, ending in 1970.

The model was validated by a comparison between its dynamic simulated values and actual values. However, it is not tested for its sensitivity to coefficient change, to exogenous shocks, or to random perturbation. The dynamic simulation was performed by a computer program utilizing the Gauss-Seidel iteration method.

Since this has been the first trial and because of the sample size and the inaccuracy of data, the author has pointed to the limitations of the model and recommended future research on this line. These recommendations can be summarized as follows [1, pp. 130-139]:

1. Updating and improving the model whenever new data is available,
2. Model maintenance by re-estimating the coefficients, revising the individual equations, and validation testing of subsystems,
3. Adding more significant new variables when available,
4. Increasing the number of sectors,
5. Using data from more recent years to re-estimate the input-output table coefficients to capture the effects of changing technology,
6. Testing the sensitivity of the basic model to coefficient changes, exogenous shock, or random perturbation.

The Econometric Model of Sudan developed by Marzouk is critically evaluated by Sapir [20], who indicated that the techniques used in this model are similar to those applied in studies of Brazil, Mexico, and the U.S. This methodology, according to Sapir, results sometimes in meaningless estimators, and he doubts the long-run investment multipliers derived from this model. Instead of relating the value added in each sector to components of aggregate final demand through empirical approximations of input-output coefficients, Sapir emphasizes the necessity of making imports an explicit part of the model. His proposed methodology (with some modification) is:

Let

A = n x n matrix of technical coefficients, [aij],

F_i = final demand for commodity i,

M_i = imports of commodity i,

Y_i = value added in sector i,

X_i = gross domestic output of sector i,

then

$$X_i + M_i = \sum_{j=1}^{n} aijX_j + F_i \tag{1}$$

$$Y_i = X_j - \sum_{i=1}^{n} aijX_i \tag{2}$$

in matrix form (1) and (2) become:

$$X + M = AX + F \tag{3}$$

$$Y = BX \tag{4}$$

where B = n x n matrix = $(I - A')$

Substituting the value of X from (3), after rearranging, equation (4) becomes

$$Y = B(I - A)^{-1} (F - M) \tag{5}$$

If there are p final demand sectors represented by a p-vector, R, and assuming the share of each final demand sector from each commodity is a constant ratio

which can be represented by an nxp matrix, H, then final demand can be written as:

$$F = HR \tag{6}$$

Also imports can be written as

$$M = \hat{m}\ X \tag{7}$$

where $\hat{m}$ is an n x n diagonal matrix of a vector of import coefficients. Thus a link between value added and imports is made by substituting for X from equation (4):

$$M = m\ B^{-1}\ Y \tag{8}$$

then substituting for F and M in equation (5):

$$Y = B(I - A)^{-1}\ [HR - \hat{m}\ B^{-1}\ Y] \tag{9}$$

or

$$Y = [I + B\ (I - A)^{-1}\ \hat{m}\ B^{-1}]^{-1}\ B\ (I - A)^{-1}\ HR \tag{10}$$

$$\text{If} \quad P = I + B\ (I - A)^{-1}\ \hat{m}\ B^{-1} \tag{11}$$

$$\text{and} \quad Q = B(I - A)^{-1}\ H \tag{12}$$

$$\text{then} \quad Y = (P^{-1}Q)\ R \tag{13}$$

The columns of the matrix $P^{-1}Q$ must sum to not more than unity, which is not the case in Marzouk's formulation. Sapir warns against pitfalls when introducing input-out relations into macroeconomic models and describes Marzouk's results:

> "... Marzouk's results cast doubt on long-run (investment) multipliers which could be derived from this model: in particular, fiscal policy would appear to have more impact on gross product than it actually should."

The ADAR study, also developed agricultural and transport models in addition to the macro-economic model. Saaty [19] in his paper outlines the methodology adopted in developing an adaptive master transport plan based on the above econometric model of the economy under four scenarios - the reference projection, agriculture for export, balanced regional growth, and Arab-African interface. According to the author the study used an emerging operations research theory of hierarchies and priorities, then the scenarios were combined to generate a composite scenario.

2.3 Models for Planning

In spite of the availability of some economic models for Sudan, there is no explicit reference in the formulated plan documents or the literature surveyed to a standard or formal model utilized in drawing any of the plans except for the first plan, 10-year plan, where input-output models were used. One of the problems encountered in Africa and other developing countries is that most of the time a significant amount of information of a factual and quantitative nature is already available at the operative level which if used could lead to substantial improvements in the formulation and execution of development policy [22]. Except for the first plan there were no quantitative studies to show the structure of the economy just before the plan; even the national income account data were not available for some recent years prior to a plan [21]. This is of course true of many developing countries [15] where there is increasing contradiction between what is planned to happen in four or five years time and what is actually happening at the moment.

Government policies need to be shaped in the light of evidence concerning past economic growth, current problems, and prospects for the future. This requires reasonably reliable statistical estimates be available concerning past

and present successes and failures. The Sudan has the problems of faulty statistics [14], data gaps, and lack of comprehensive data gathering by government and semi-official bodies. Many of the problems encountered in the first two economic development plans are elaborately discussed in [2, 12, 14, 33] as mentioned in the last chapter.

3. THE RAS METHOD

The ideal situation for having an up-to-date input-output table is to construct it annually in conjunction with the estimation of national accounts; this procedure is followed in the Netherlands and Norway. However, it is not practical for countries which do not have the resources to compile such statistical data on an annual basis.

Since most of the coefficients are usually found to be sufficiently stable over the period of a few years, there is no need for full annual tables [25]. Besides, it takes at least two to three years to prepare input-output tables. Therefore, techniques have been developed to update existing input-output tables from a past year to a current year when certain national accounting data is available. These techniques can take care of the regular changes in input-output coefficients, and are reasonably accurate over a period of five to ten years [25]. The decision of how frequently input-output tables should be estimated depends on the resources available, the stability of input coefficients, and the accuracy of updated tables.

The basic method of updating known as RAS was developed by Professor Stone and his colleagues at Cambridge during the early sixties. National accounting data usually provides estimates of final demand vectors, the primary inputs into industries, and foreign trade (imports and exports). If commodity taxes are also included in this information, then all entries of an input-output table are available except the flow matrix. The problem is thus to adjust a matrix to fit new constraints.

The RAS method consists of finding two sets of multipliers, one to adjust the rows (called substitution multipliers), and the other to adjust the columns (called fabrication multipliers) so that the elements of the adjusted flow matrix will sum to the desired row and column totals relating to the current year. Thus an implied assumption is that each effect works uniformly.

Mathematically the RAS method is as follows:

$$A_1 = \hat{R}\, A_o\, \hat{S} \tag{14}$$

where

A_1 = the new coefficient matrix

A_o = the basic-year coefficient matrix

$\hat{R}$ = a matrix with vector R in diagonal

$\hat{S}$ = a matrix with vector S in diagonal

$$X_o = A_o\, \hat{Q}_o \tag{15}$$

or

$$A_o = X_o\, \hat{Q}_o^{-1} \tag{16}$$

where

X_o = the flow matrix for year '0' (basic year)

$\hat{Q}_o$ = a matrix with vector Q_o (the total output of the basic year) in the diagonal.

To find the vectors R (substitution multipliers) and S (fabrication multipliers) we have:

$$\begin{aligned} X_1 &= A_1\, \hat{Q}_1 \\ &= (\hat{R}\, A_o\, \hat{S})\, \hat{Q}_1 \end{aligned} \tag{17}$$

Let U equal row totals vector; then

$$U_1 = X_1\, i \tag{18}$$

where i is a unit column vector.

$$U_1 = (\hat{R}\, A_o\, \hat{S})\, \hat{Q}_1\, i$$

$$= \hat{R}\, A_o\, \hat{Q}_1\, \hat{S}\, i$$

$$= \hat{R}\, (A_o\, \hat{Q}_1)\, S \qquad (19)$$

Let V equal column total vector; then

$$v_1 = x_1'\, i \qquad (20)$$

$$v_1' = i'\, x_1$$

$$= i'\, (\hat{R}\, A_o\, \hat{S})\, \hat{Q}_1$$

$$= i'\, \hat{R}\, A_o\, \hat{Q}_1\, \hat{S}$$

$$= R'\, (A_o\, \hat{Q}_1)\, \hat{S} \qquad (21)$$

Solving (19) and (21) simultaneously will give the values of R and S vectors and hence find A_1 of equation (14) and then X_1. However, the usual and most convenient algorithm for solving them is an iterative one.

For this study a computer program using FORTRAN language is developed; a flow diagram and the program listing is shown in Appendix II. The algorithm for the iterative method is:

Step 1. Given the base year flow matrix, X_o, gross output vector, Q_o, row sum vector, U_o, and column sum vector, V_o. Given also for the current year the total output vector, Q_1, the row sum vector, $\bar{U}_1$, and the column sum vector, $\bar{V}_1$.

Step 2. From Year '0' information

$$A_o = X_o \hat{Q}_o^{-1}$$

Step 3. Assuming no technical change then

$$X_1 = A_o \hat{Q}_1$$

Step 4. From the value of X_1 in '3' calculate u and v, the row sums and column sums, respectively, and compare their values with $\bar{u}$ and $\bar{v}$ of year minus one. A discrepancy means that the assumption of unchanged coefficients is not justifiable and it is then necessary to adjust the matrix X_1 to fit the constraints $\bar{v}$ and $\bar{u}$.

Step 5. To adjust X_1, start with row multipliers, R_1, where:

$$R_1 = \frac{\bar{U}}{u_1}$$

and multiply each row with its corresponding R_1 so as to meet the constraint $\bar{U}$.

Step 6. Compare the column totals resulting from Step 5 with $\bar{V}$ and find the set of column multipliers, S_1, where:

$$S_1 = \frac{\bar{V}}{V_1}$$

Step 7. Step 6 may lead to a discrepancy between row totals and $\bar{U}$, therefore a second set of row multipliers, R_2, is obtained.

Step 8. Columns may then require further adjustments and consequently obtain S_2, etc.

Step 9. When no further adjustments are needed then R and S are found by:

$$R = R_1 R_2 R_3 \ldots R_{N-1} R_N = \prod_{i=1}^{N} R_i$$

and

$$S = S_1 S_2 S_3 \ldots S_{N-1} S_N = \prod_{i=1}^{N} S_i$$

where N is the number of iterations.

As a simple illustration let the input-output matrix be 3 x 3 and:

$$A_o = \begin{bmatrix} a^o_{11} & a^o_{12} & a^o_{13} \\ a^o_{21} & a^o_{22} & a^o_{23} \\ a^o_{31} & a^o_{32} & a^o_{33} \end{bmatrix}$$

$$A_1 = \begin{bmatrix} a^1_{11} & a^1_{12} & a^1_{13} \\ a^1_{21} & a^1_{22} & a^1_{23} \\ a^1_{31} & a^1_{32} & a^1_{33} \end{bmatrix}$$

then

$$\hat{R} A_o \hat{s} = A_1$$

$$\begin{bmatrix} R_1 & 0 & 0 \\ 0 & R_2 & 0 \\ 0 & 0 & R_3 \end{bmatrix} \begin{bmatrix} a^o_{11} & a^o_{12} & a^o_{13} \\ a^o_{21} & a^o_{22} & a^o_{23} \\ a^o_{31} & a^o_{32} & a^o_{33} \end{bmatrix} \begin{bmatrix} S_1 & 0 & 0 \\ 0 & S_2 & \\ 0 & 0 & S_3 \end{bmatrix} = \begin{bmatrix} a^1_{11} & a^1_{12} & a^1_{13} \\ a^1_{21} & a^1_{22} & a^1_{23} \\ a^1_{31} & a^1_{32} & a^1_{33} \end{bmatrix}$$

or

$$\begin{bmatrix} R_1 (a^{\circ}_{11}) S_1 & R_1 (a^{\circ}_{12}) S_2 & R_1 (a^{\circ}_{13}) S_3 \\ R_2 (a^{\circ}_{21}) S_1 & R_2 (a^{\circ}_{22}) S_2 & R_2 (a^{\circ}_{23}) S_3 \\ R_3 (a^{\circ}_{31}) S_1 & R_3 (a^{\circ}_{32}) S_2 & R_3 (a^{\circ}_{33}) S_3 \end{bmatrix} = \begin{bmatrix} a^1_{11} & a^1_{12} & a^1_{13} \\ a^1_{21} & a^1_{22} & a^1_{23} \\ a^1_{31} & a^1_{32} & a^1_{33} \end{bmatrix}$$

Bacharach [3] showed that the RAS method produces a unique solution, and if a particular cell was zero in the base matrix, it will remain zero in the final matrix; i.e., no negative cells appear in the final matrix. Another mathematical property is that the method soon converges on the solution and thus requires less computing time. Tests have shown that when a matrix is estimated by RAS from a previous year it will give a somewhat better estimate of a succeeding year than a matrix of a previous year; i.e., $\hat{R}\, A_o\, \hat{S}$ is closer to A_1 than A_o is.

The RAS method can also utilize exogenous information when some coefficients or inputs are preidentified and thus can be excluded from the adjustment process. In such a case these known cells are brought to zero in both A_o and A_1 while their values are deducted from U_o, V_o, $\bar{U}_1$, and $\bar{V}_1$. This modified RAS method leads to a greater improvement in the accuracy of the updating method as its application to U.K input-output tables has shown that substantially improved results can be obtained when relatively small amounts of additional information about some preselected major coefficients are incorporated into the updating process [25]. It should be pointed out, however, that when using the modified RAS method the row and column multipliers have no economic significance.

The RAS method in effect minimizes a particular distance function just like the other four methods of Friedlander, Matuszewski etl., Theil, and Almon, each of which minimizes a different distance function. The distance function which is to be minimized in the RAS method has the curious expression [13]:

$$\Sigma \left[x_{ij} \log \left(\frac{\bar{x}_{ij}}{x^{\circ}_{ij}} \right) \right]$$

In conclusion,the RAS method is by far the simplest of the methods and it also preserves signs. Its associated multipliers can be interpretted economically and used as a basis for projection.

4. DEVELOPMENT OF A NEW INPUT-OUTPUT MODEL FOR SUDAN

In order to develop the new input-output table for Sudan, six successive steps are performed:

Step 1. Convert the 1962/63 input-output table of Sudan to the form that conforms with the existing classification of the national accounting data - obtain the reconstructed 1962/63 input-output table.

Step 2. Update the reconstructed 1962/63 table by 1972/73 national accounting data.

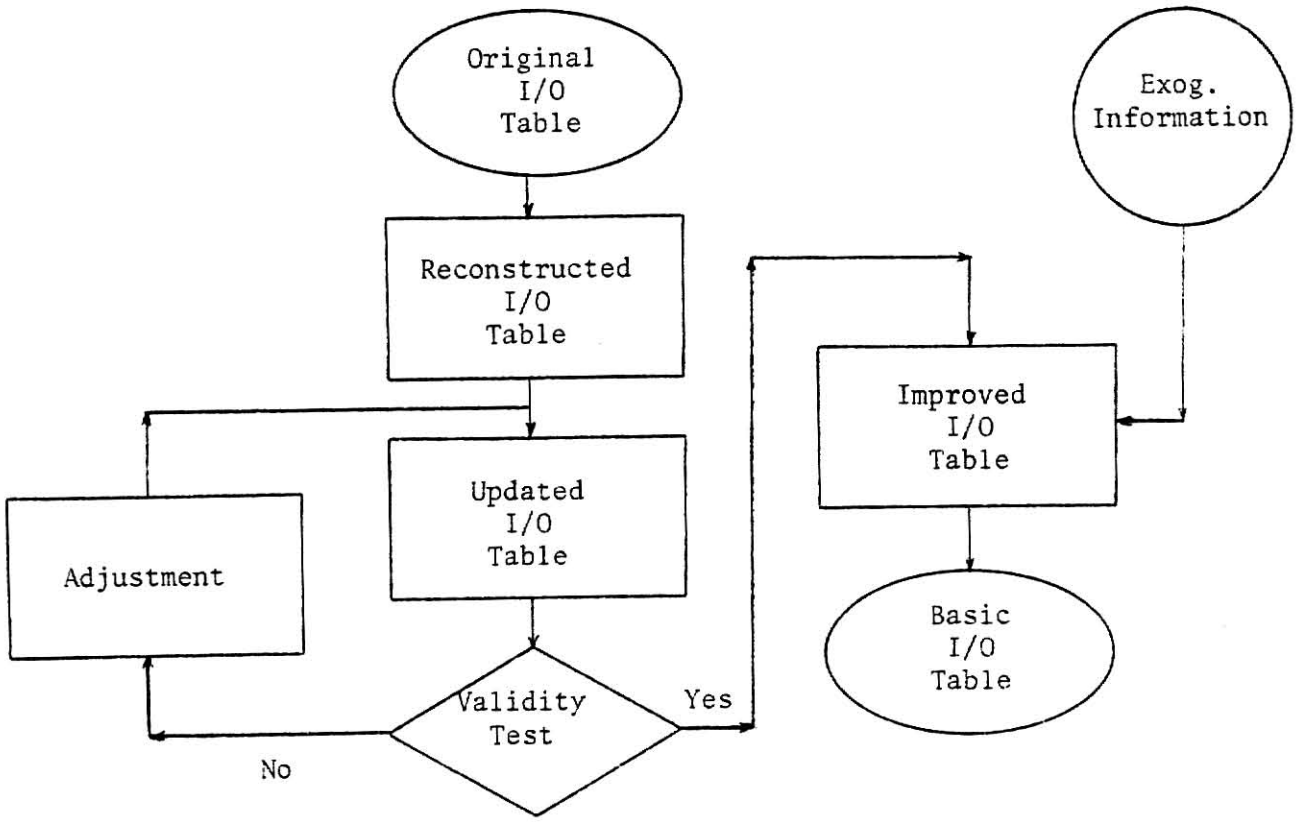
Step 3. Validate the input-output table of 2 by testing it with 1973/74 data.

Step 4. Improve the model obtained in Step 3 by exogenous information and conception of the new structure of the economy,i.e., by fixing the values of some cells and adding others.

Step 5. Use the input-output table of Step 4 as the basic table for the future.

Step 6. For the purpose of this study the basic table is updated to 1974/75.

Diagramatically the methodology is shown below:



4.1 Detail of Development Steps and Results

This section shows the details of each step and the results obtained.

Step 1. The original 1962/63 input-output table for Sudan is as shown in Appendix I. The classification of the economic activities according to this table were abandoned by 1966 to follow the "System of National Accounts" - (S.N.A.) [24]. The equivalence between the old grouping of economic activities and the new categories is given in [6], Appendix III. The conversion or reconstruction is done arbitrarily. The reconstructed 1962/63 input-output table is shown in Appendix IV.

Step 2. This step is performed using the RAS method to update the reconstructed 1962/63 table by 1972/73 data. The source of data for this step and other steps is the National Income Accounts [9] and other references [4-11, 17, 26-29]; use is also made of general information about the system and methodology of the adopted classification found in [24,30-32]. However, some of this data is far from being in a form suitable for direct insertion into the input-output table. Final demand is subjectively allocated most of the time, and although in the input side more detailed information is provided, still some subjective allocation of imports and import duties was practiced. The producers of government services and the producers of private nonprofit services to households were considered as producing sectors to conform with the classification followed. The 'producers of government services' was taken to be exogenous to the RAS method. The data used in this step are all the entries shown in the table of Appendix V except the upper left hand quadrant which is the updated interflow matrix.

Step 3. To test for the validity of the table derived in Step 2, the total output data of 1973/74 is used to predict the intermediate input for 1973/74, which is actually given. The validation is done as follows:

(a) Predict the intermediate input row vector of 1973/74, v^*, from the coefficient matrix, A, of 1972/73 and the total output of 1973/74, Q.

$$V^* = \hat{Q}\, A'\, i$$

(b) Find the percentage deviation vector, σ, of the predicted input, v^*, from the given input vector for 1973/74, v.

$$\sigma = \frac{v - v^*}{v} \cdot 100$$

If $| \sigma_j | < 10\%$ then the 1972/73 table is acceptable; otherwise go to the next step.

(c) Investigate those σ's where $| \sigma_j | > 10\%$ and their corresponding statistical data are given or estimated for detection of outliers and their correction.

In this exercise, however, only two values greater than 10% are detected; the values are as shown in Table 1. As can be seen sector 7, the transport sector, has the highest deviation of about 20%; when looking at the trend of intermediate inputs for this sector for four years (1971/72 to 1974/75), it shows a low value for 1972/73 compared to the previous years, and since no major technical change in this sector could be justified, it is assumed that a misrecording has taken place and the value is adjusted in accordance with the trend. The same procudure was applied to the compensation of employees for this sector. Other minor adjustments were performed on the estimation and breakdown of import duties for which different values were given in some records.

The procedure leads to an improved input-output table for 1972/73 as shown in Appendix VI. The percentage deviations for the calculations from this table are acceptable as can be seen from Table 2.

Table 1 Percentage deviations, σ.

Sector No.	% Deviation
1	9.81
2	-9.44
3	-9.33
4	3.47
5	1.69
6	9.1
7	20.04
8	13.63
9	3.91
10	1.52
11	0.0

Table 2. Percentage deviation, σ, from validated 1972/73 Table.

Sector No.	% Deviation
1	9.27
2	-5.74
3	-5.75
4	2.45
5	1.69
6	7.03
7	1.53
8	-6.35
9	3.91
10	1.52
11	0.0

Step 4. In this step exogenous information for updating is incorporated and thus the modified RAS method is used. As an example, the percentages of electric energy consumption among some categories of the economy are [19]:

Residential	50%
Industrial	38%
Agricultural	3.5%
Interdependent	8.5%

Some cells which were originally zero are perceived to be non zero, such as input of petroleum products into manufacturing and the electricity and water sectors, etc. Four zero cells are thus modified, as well as seven cells of government services being exogenously recorded. The results of this step are shown in Appendix VII.

Step 5. The input-output table developed in Step 4 will now be designated as the basic table for future use.

Step 6. In order to utilize the input-output table for the next chapter it needs to be updated to the base year of the plan, 1976/77, but since the National Accounting data for Sudan is only available for 1974/75, the basic table is updated to this year. Appendix VIII shows the basic input-output table updated to 1974/75. The modified RAS method is used again where cell values of the producers of government services are exogenously given.

5. CONCLUDING REMARKS

In this chapter a brief survey of economic models for Sudan is conducted. Also the RAS technique of updating input-output tables is elaborately explained and the alogrithm is stated in a more usable and programmable form.

The data for this chapter represented the biggest challenge, and although the main source of data is from the statistical data publications for Sudan, it is not, however, in a cast which makes it readily insertable in the input-output table and hence its adaptation required a huge effort and many references.

Thus this chapter has successfully developed a new rather than updated input-output table for Sudan from a 25-year old table by reconstruction, RAS, and feedback techniques which represent a new methodology of procuring an input-output table for a developing country instead of relying on borrowing other countries' tables.

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APPENDIX I

Original 1962/63 input-output table

Intermediate flow and primary inputs (LS Thousand)

	Agr.	Live-stock	Fores.	Fish. & Marine Prod.	Trans. & Distrib.	Min.	Manuf. Indus.	Pub. Util.	Craft Indus.	Build. & Civil Engg.	Banks & Insur.	Dom. Serv.	Misc. Serv.	Owner. of Build.
Agriculture		1900					5621		1650					
Livestock							81		320					
Forestry					40		64		2512	2637				
Fishing & Marine Products														
Transport & Distribution	15940	1107	2907	35		951	5014	553	2	4920	73		204	
Minerals									19	75				
Manufacturing		1200			700					2050			140	
Public Utilities	100				474		568				102		22	
Craft Industries														
Building & Civil Eng.														
Banks & Insurances					1700		496	22		300			9	
Domestic Services														
Miscellaneous Services					123		753	17						
Ownership of Buildings														
Total purchases from other industries	16040	4207	2907	35	3037	951	12597	592	4503	9982	175		375	
Imports Merchandise	7339		85	15	3943		5977	900	10	8852	423		454	
Invisible imports & adjustment	2607				1000		193			6600			300	
Indirect taxes	783		27	5	2805		2861	187	2	3152	100		22	
Charges and sales of Govern.	216	180			2160									
Final Output	140230	40054	34550	8027	64068	278	7590	2221	12086	27354	3273	1860	18144	
Total input	167215	44441	37569	8082	77013	1229	29218	3900	16601	55940	3971	1860	19295	

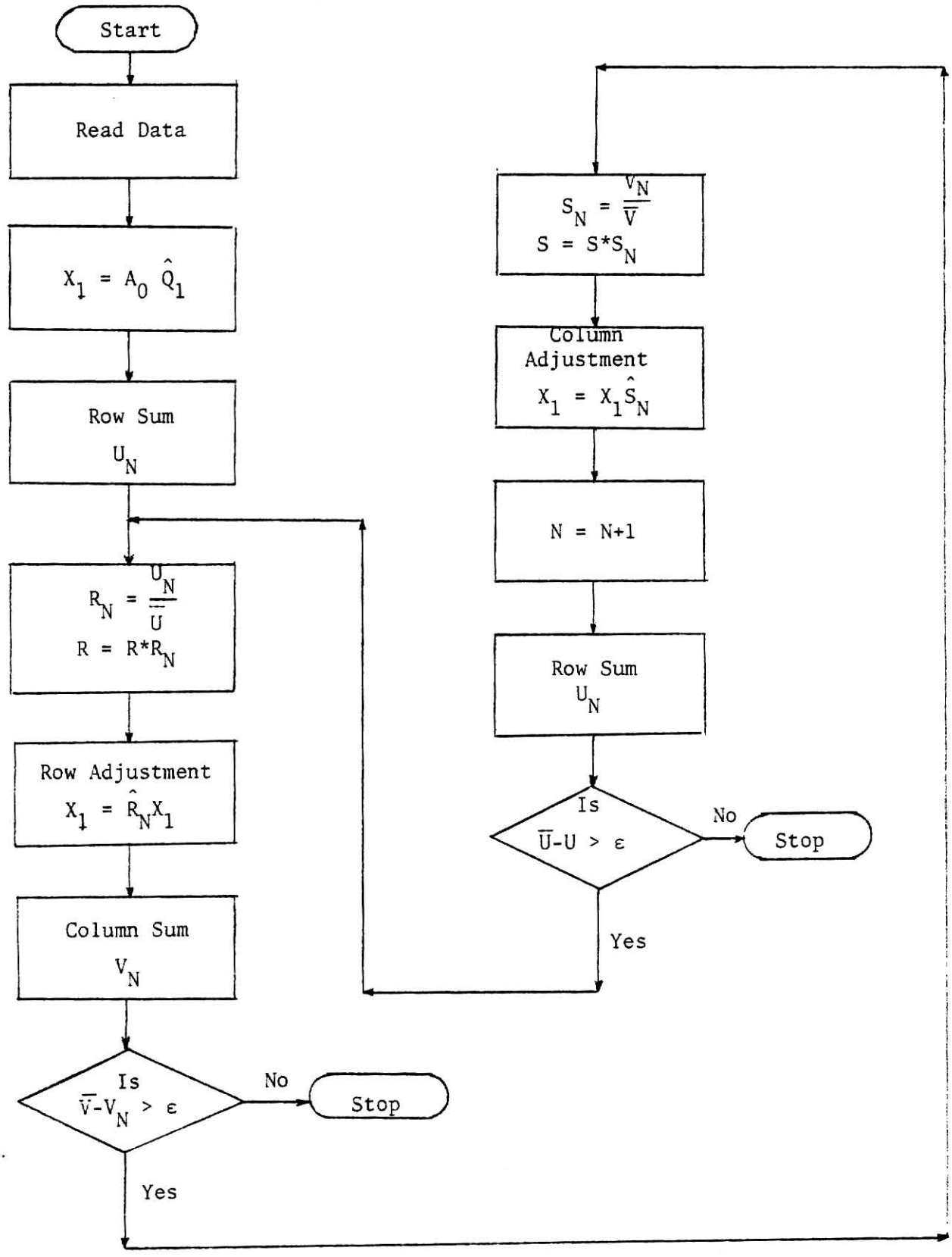
Source: "National Income of Sudan in 1961/1962 (with preliminary estimates for 1962/63)", Department of Statistics, Khartoum.

Total Sales to other Indust.	Final Output						Total Output
	Exports	Govern.	Non-Gov. Educat.	House-holds	Capital	Stocks	
9171	75117	243		88171	-5487	-5487	167215
401	2151	67		41822			44441
5253	5720	10		26586			37569
	80			8002			8082
31706	4000	4168	12	31714	5413		77013
94	81			1054			1229
4090	4351	580		19486	711		29218
1266		597	154	1883			3900
				16601			16601
2147		157		9893	43743		55940
2527			33	1411			3971
				1860			1860
893				18402			19295
				15725			15725
57548	91500	5822	199	282610	44380	-5487	482059
27998		4590	127	36068	18617	+3271	87400
10700		2400		1400			14500
12771		2288	50	29121	3387		47617
2556				1044			3600
370486		32200	1955				404641
482059	91500	47300	2331	350243	66384	-2216	1039817

Appendix II

The flow diagram and program listing

of the RAS method


Start
Read Data
$X_1 = A_0 \hat{Q}_1$
Row Sum
U_N
$R_N = \frac{U_N}{\bar{U}}$
$R = R*R_N$
Row Adjustment
$X_1 = \hat{R}_N X_1$
Column Sum
V_N
Is
$\bar{V}-V_N > \varepsilon$
No
Stop
Yes
$S_N = \frac{V_N}{\bar{V}}$
$S = S*S_N$
Column Adjustment
$X_1 = X_1 \hat{S}_N$
N = N+1
Row Sum
U_N
Is
$\bar{U}-U > \varepsilon$
No
Stop
Yes

```
C          INPUT-OUTPUT TABLES UPDATING BY THE
C                              RAS
C                             METHOD
C
C          KANSAS STATE UNIVERSITY,MANHATTEN,KANSAS
C
C*************************************************************************
C*ALGORITHM
C
C          SEE PAGE    OF DISERTATION PLEASE
C
C*************************************************************************
C*LANGUAGE
C
C          FORTRAN
C*************************************************************************
C
C          PROGRAMED BY MUSA M. BABIKER
C
C          DATE OF LAST REVISION JULY 2,1980
C*************************************************************************
C*PROGRAM
C
C  SCALARS
C
C  NS      NUMBER OF SECTORS
C  NMOD    FOR UNMODEFIED RAS NMOD=0
C          FOR MODEFIED RASAS NMOD=1
C  NYY     NUMBER OF YEARS :UPDATING HORIZON
C  NI      NUMBER OF ITERATIONS
C  VECTORS OF LEGTH NS
C  QO      TOTAL OUTPUT VECTOR FOR YEAR 0 (EASIC YEAR)
C  UO      BASIC YEAR ROW CONSTRAINT VECTOR
C  VO      BASIC YEAR COLUMN VECTOR
C  QNY     TOTAL OUTPUT FOR YEAR NY VECTOR
C  USNY    YEAR NY ROW CONSTRAINT VECTOR
C  VSNY    YEAR NY COLUMN CONSTRAINT VECTOR
C  R       SUPSTITUTION MULTIPLIER VECTOR
C  S       FABRICATION MULTIPLIER VECTOR
C  UNI     ROW CONSTRAINT VECTOR IN ITERATION NI
C  VNI     COLUMN CONSTRAINT VECTOR IN ITERATION NI
C  RM      ROW MULTIPLIERS
C  CM      COLUMN MULTIPLIERS
C
C  MATRICES OF SIZE NSXNS
C
C  XO      I/O TABLE FLOW MATRIX FOR YEAR 0 (BASIC YEAR)
C  AO      I/O TABLE COEFFICIENT MATRIX FOR YEAR C
C  XNY     I/O TABLE FLOW MATRIX FOR YEAR NY
C  ANY     I/O TABLE COEFFICIENT MATRIX FOR YEAR NY
```

```
C  QOHAT   MATRIX WITH THE VECTOR QO IN DIAGONAL
C  QNYHAT  MATRIX WITH THE VECTOR QNY IN DIAGONAL
C  RHAT    MATRIX WITH THE VECTOR R   IN DIAGONAL
C  SHAT    MATRIX WITH THE VECTOR S   IN DIAGONAL
C
C  WORK VECTORS AND MATRICES
C
C  M       NS X 1
C  L       NS X 1
C  D       DETERMINANT OF MATRIX INVERTED
C  DP      DOUBLE PRECISION MATRIX
C  DUM     DUMMY MATRIX
C
C*****************************************************************************
C
      DIMENSION QO(11),UO(11),VO(11),QNY(11),USNY(11),VSNY(11),R(11),
     *S(11),UNI(11),VNI(11),XO(11,11),AC(11,11),XNY(11,11),ANY(11,11),
     *QOHAT(11,11),QNYHAT(11,11),RHAT(11,11),SHAT(11,11),DUM(11,11),
     *M(11),L(11),RM(11),CM(11),UV(11),UVHAT(11,11)
      DOUBLE PRECISION D,DP(11,11)
C
C  FORMAT
C
    1 FORMAT(10F8.5)
    2 FORMAT(8F10.5)
    3 FORMAT('-',T15,11('SECTOR',2X),4X,'ROW',11X,'TOTAL')
    4 FORMAT(' ',T17,11(I2,6X),'MULTIPLIERS')
    5 FORMAT('0',T12,105('-'))
    6 FORMAT('-',T2,'SECTOR',T9,I2,T15,11(F7.3,1X),5X,F5.3,5X,F8.3)
    7 FORMAT('0',T4,'COLUMN')
    8 FORMAT(' ',T2,'MULTIPLIERS',T15,11(F6.3,2X))
    9 FORMAT('1',' ')
   10 FORMAT(20X,I2,38X,I2,13X,I1)
   11 FORMAT('1',T43,'UP-DATED INPUT-OUTPUT TABLE FOR  ',1X,
     *'YEAR         ',10X,'NI =',I4)
   12 FORMAT('1',T43,' (I-A)')
   13 FORMAT('1',T43,' (I-A) INVERSE ')
   14 FORMAT('-',7(E16.6,2X))
   15 FORMAT('-','**** ROWS & COLMUNS TOTALS OF BASIC MATRIX NOT EQUAL',
     *'****',' SUM1 ',F10.3,' SUM2 ',3F10.3)
   16 FORMAT('-','**** ROWS & COLMUNS TOTALS OF NEW   MATRIX NOT EQUAL',
     *'****',' SUM3 ',F10.3,' SUM4 ',F10.3)
   17 FORMAT('-',T2,'SECTOR',T9,I2,T15,11(F9.6,1X))
C
C  READ DATA FOR BASIC YEAR
C
      READ(5,10)NS,NYY,NMOD
      READ(5,1)((XO(I,J),J=1,NS),I=1,NS)
      READ(5,2)(QO(I),I=1,NS)
      READ(5,2)(UO(I),I=1,NS)
```

```
      READ(5,2)(VO(I),I=1,NS)
C
      NI=0
      NY=1
      DO 23 I=1,NS
      UV(I)=1.0
      RM(I)=1.0
   23 CM(I)=1.0
C
C  READ DATA FOR SUCCESSIVE YEARS
C
   50 READ(5,2)(USNY(I),I=1,NS)
      READ(5,2)(QNY(I),I=1,NS)
      READ(5,2)(VSNY(I),I=1,NS)
C
C  TEST ROW TOTALS ARE EQUAL TO COLUMNS TOTAL
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      DO 18 I=1,NS
      SUM1=SUM1+UO(I)
      SUM2=SUM2+VO(I)
      SUM3=SUM3+VSNY(I)
       SUM4=SUM4+USNY(I)
   18 CONTINUE
      PRINT15,SUM1,SUM2,SUM3,SUM4
      IF((SUM1-SUM2).GT.0.001.OR.(SUM1-SUM2).LT.-.001)GO TO 100
C
C  VECTOR QO AND QNY AS DIAGONALS OF MATRIX QOHAT & QNYHAT
      CALL CVDM(QO,QOHAT,NS,0)
      CALL CVDM(QNY,QNYHAT,NS,0)
C
C  COMPUTE THE COEFFICIENT MATRIX AO
      CALL CONVT(NS,NS,1,QOHAT,DP,0)
      CALL DMINV(DP,NS,D,L,M)
      CALL CONVT(NS,NS,2,QOHAT,DP,0)
      CALL GMPRD(XO,QOHAT,AO,NS,NS,NS)
C
C  YEAR 0 COEFFICIENTS APPLIED TO YEAR 1 OUTPUTS,X1=          (STEP D)
      CALL GMPRD(AO,QNYHAT,XNY,NS,NS,NS)
C
C  ROW CONSTRAINTS AND CALCULATTION OF R
      CALL RSUM(XNY,UNI,NS,NS,0)
C
      DO 20 I=1,NS
      IF(UNI(I))201,202,201
  201 R(I)=USNY(I)/UNI(I)
      GO TO 20
  202 R(I)=0.0
```

```
   20 RM(I)=RM(I)*R(I)
C
C  ADJUSTMENT OF MATRIX ALONG ROWS & CALCULATION OF S
   40 CALL CVDM(R,RHAT,NS,0)
      CALL GMPRD(RHAT,XNY,DUM,NS,NS,NS)
      CALL MCPY(DUM,XNY,NS,NS,0)
      CALL CSUM(XNY,VNI,NS,NS,0)
      NI=NI+1
C
      DO 21 I=1,NS
      IF(VNI(I))211,212,211
  211 S(I)=VSNY(I)/VNI(I)
      GO TO 21
  212 S(I)=0.0
   21 CM(I)=CM(I)*S(I)
C
C  TEST IF VNI=VSNY
      I=1
      NSS=NS+1
   60 IF((VSNY(I)-VNI(I)).GT.0.0001.OR.(VSNY(I)-VNI(I)).LT.-0.0001)GO
     *TO 61
      I=I+1
      IF(I.EQ.NSS)GO TO 30
      GO TO 60
C
C  ADJUSTMENT OF MATRIX ALONG COLUMNS & CALCULATION OF R (STEP F)
   61 CALL CVDM(S,SHAT,NS,0)
      CALL GMPRD(XNY,SHAT,DUM,NS,NS,NS)
      CALL MCPY(DUM,XNY,NS,NS,0)
      CALL RSUM(XNY,UNI,NS,NS,0)
C
      DO 22 I=1,NS
      IF(UNI(I))221,222,221
  221 R(I)=USNY(I)/UNI(I)
      GO TO 22
  222 R(I)=0.0
   22 RM(I)=RM(I)*R(I)
C
C  AVOID OVERFLOW OF MULTIPLIERS WHEN USING MODEFIED RAS METHOD ( NMOD )
      I=1
      IF(NMOD)24,25,24
   24 IF(RM(I).GE.100.0)GO TO 241
      IF(CM(I).GE.100.0)GO TO 242
      GO TO 243
  241 RM(I)=99.0
      GO TO 243
  242 CM(I)=99.0
  243 I=I+1
      IF(I.EQ.NSS)GO TO 25
      GO TO 24
```

```
   25 CONTINUE
      IF(NI.GT.100.0)GO TO 95
C
C  TEST IF UNI=USNY
      I=1
   42 IF((USNY(I)-UNI(I)).GT.0.0001.OR.(USNY(I)-UNI(I)).LT.-0.0001)GO
     *TO 40
      I=I+1
      IF(I.EQ.NSS)GO TO 30
      GO TO 42
C
   30 IF(NY.EQ.NYY)GO TO 95
C
C  SET XO=XNY , UO=UNY , VO=VNY , QO=QNY
      CALL MCPY(XNY,XO,NS,NS,0)
      CALL RSUM(XO,UO,NS,NS,0)
      CALL CSUM(XO,VO,NS,NS,0)
C
      DO 31 I=1,NS
   31 QO(I)=QNY(I)
C
      NY=NY+1
      GO TO 50
C
   95 WRITE(6,11)NI
      WRITE(6,3)
      WRITE(6,4)(I,I=1,NS)
      WRITE(6,5)
      DO 33 I=1,NS
   33 WRITE(6,6)I,(XNY(I,J),J=1,NS),RM(I),UNI(I)
      WRITE(6,5)
      WRITE(6,7)
      WRITE(6,8)(CM(J),J=1,NS)
      WRITE(6,9)
C  COMPUTE THE COEFF. MATRIX ANY
      CALL CONVT(NS,NS,1,QNYHAT,DP,0)
      CALL DMINV(DP,NS,D,L,M)
      CALL CONVT(NS,NS,2,QNYHAT,DP,0)
      CALL GMPRD(XNY,QNYHAT,ANY,NS,NS,NS)
      DO 39 I=1,NS
   39 WRITE(6,17)I,(ANY(I,J),J=1,NS)
      CALL CVDM(UV,UVHAT,NS,0)
      CALL GMSUB(UVHAT,ANY,DUM,NS,NS)
      WRITE(6,12)
      DO 37 I=1,NS
   37 WRITE(6,17)(DUM(I,J),J=1,NS)
      CALL CONVT(NS,NS,1,DUM,DP,0)
      CALL DMINV(DP,NS,D,L,M)
      CALL CONVT(NS,NS,2,DUM,DP,0)
      WRITE(6,13)
```

```
      DO 38 I=1,NS
   38 WRITE(6,14)(DUM(I,J),J=1,NS)
      WRITE(6,9)
      GO TO 99
  100 WRITE(6,15)SUM1,SUM2,SUM3,SUM4
      GO TO 99
  101 WRITE(6,16)SUM3,SUM4
   99 STOP
      END

C*********************************************************************
C  SUBROUTINE  CVDM
C
C  PURPOSE
C     CHANGE A VECTOR INTO A DIAGONAL MATRIX
C
C  USAGE
C     CALL CVDM(R,A,N,MS)
C
C  DESCRIPTION OF PARAMETERS
C
C  R       NAME OF INPUT VECTOR OF LENGTH N
C  A       NAME OF OUTPUT MATRIX
C  N       NUMBER OF ROWS & COLUMNS IN MATRIX A
C  MS      ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX A
C
C              0- GENERAL
C              1- SYMMETRIC
C              2- DIAGONAL
C
C  SUBROUTINE & FUNCTION SUBPROGRAMS REQUIRED
C          LOC
C
C*********************************************************************
C  SUBROUTINE  CVDM
      SUBROUTINE CVDM(R,A,N,MS)
      DIMENSION R(1),A(1)
      DO 3 J=1,N
      CALL LOC(J,J,IJ,N,N,MS)
    3 A(IJ)=R(J)
      RETURN
      END

C*********************************************************************
C
C     DOUBLE PRECISION MATRIX INVERSION SUBROUTINE
C
C*********************************************************************
```

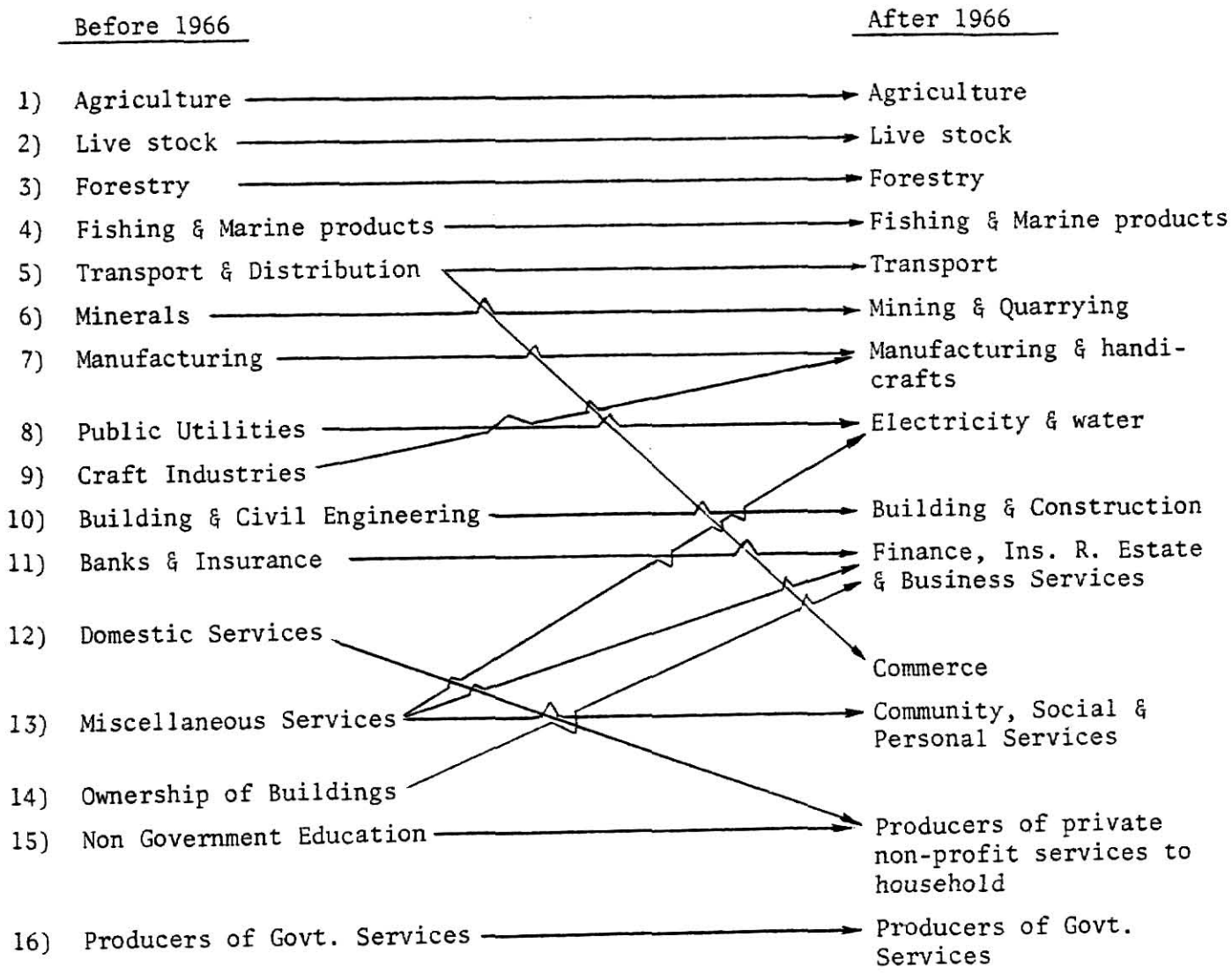
```
C
      SUBROUTINE DMINV(A,N,D,L,M)
      DIMENSION A(1), L(1), M(1)
      DOUBLE PRECISION A,D,BIGA,HOLD
C
C        SEARCH FOR LARGEST ELEMENT
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF(DABS(BIGA)-DABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
```

```
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
C
C        DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
C
C        PRODUCT OF PIVOTS
C
      D=D*BIGA
C
C        REPLACE PIVOT BY RECIPROCAL
C
      A(KK)=1.0/BIGA
   80 CONTINUE
C
C        FINAL ROW AND COLUMN INTERCHANGE
C
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
```

```
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JK=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JK+J
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
```

APPENDIX III

The equivalence between the old and new grouping


Before 1966
After 1966
1) Agriculture
2) Live stock
3) Forestry
4) Fishing & Marine products
5) Transport & Distribution
6) Minerals
7) Manufacturing
8) Public Utilities
9) Craft Industries
10) Building & Civil Engineering
11) Banks & Insurance
12) Domestic Services
13) Miscellaneous Services
14) Ownership of Buildings
15) Non Government Education
16) Producers of Govt. Services
Agriculture
Live stock
Forestry
Fishing & Marine products
Transport
Mining & Quarrying
Manufacturing & handi-crafts
Electricity & water
Building & Construction
Finance, Ins. R. Estate & Business Services
Commerce
Community, Social & Personal Services
Producers of private non-profit services to household
Producers of Govt. Services

Appendix IV

Reconstructed 1962/63 input-output table

Intermediate flow and primary inputs (LS Million)

	1 Agr.	2 Min.	3 Manuf.	4 E & W	5 Constr.	6 Commerce	7 Trans.	8 Finance	9 Commu.	10 PNP	11 Govt.	Total Interm. Demand
1) Agriculture	1.9		10.248		2.637	.03	,01					14.825
2) Mining			.019		.075							.094
3) Manufacturing	1.2				2.05	.56	.25	.02	.01			4.09
4) Electricity and Water	0.1		.608			.374	.1	.102	.022	.154		1.46
5) Building and Construction								2.147				2.147
6) Commerce	2.854	0.2	4.685	.417	4.0	.143		.1	.03	.008		12.437
7) Transport	17.135	.751	1.014	.153	.92	.09		.027	.01	.004		20.104
8) Finance Services			.526	.022	.3	.704	1.0	.005		.033		2.59
9) Community Services												0
10) Private Non-Profit Services												0
11) Government Services												0
Total Purchases	23.189	.951	17.1	.592	9.982	1.901	1.36	2.401	.072	.199		57.747
Intermediate Imports												
Consumption Imports												
Capital Goods Imports												
Government (Taxes)												
Compensation of Employees												
Operating Surplus												
Fixed Capital Consumption												
VALUE ADDED												
Total inputs												

Final Demand

House-hold Consum.	Govern. Consum.	Household Capital Formation	Govern. Capital Form.	Stocks	Exports	Total Final Demand	Total Output
164.581	.320	-5.487		-5.487	83.068	242.482	257.307
1.054		0			.081	1.135	1.229
36.087	.58	.711			4.351	41.729	45.819
3.883	.597	0			0	4.48	5.94
9.893	.157	43.743			0	53.793	55.94
36.402	1.168	4.0			4.0	45.57	58.007
6.714	3.0	1.413			0	11.127	31.231
17.136						17.136	19.726
5.0						5.0	5.0
4.191						4.191	4.191
284.941	5.822			-5.487	91.5	426.643	484.39

Appendix V

Updated input-output table for 1972/73

Intermediate flow and primary inputs (LS Million)

	1 Agr.	2 Min.	3 Manuf.	4 E & W	5 Constr.	6 Commerce	7 Trans.	8 Finance	9 Commu.	10 PNP	11 Govt.	Total Interm. Demand
1) Agriculture	4.273		79.812		2.754	.431	.074				6.7*	94.054
2) Mining			2.213		1.175							3.388
3) Manufacturing	22.535				17.94	67.151	15.346	.884	1.841		.4*	126.097
4) Electricity & Water	.136		2.854			3.236	.443	.325	.292	6.511	.5*	14.297
5) Building & Construction								7.606			.4*	8.006
6) Commerce	6.982	.718	39.689	5.722	4.56	2.234		.576	.719	.611	1.5*	63.309
7) Transport	43.275	2.782	8.868	2.167	1.083	1.451		.16	.248	.315	2 *	62.35
8) Finance Services			7.544	.511	.579	18.617	13.537	.049		4.263		45.1
9) Community Services												
10) PNP Services												
11) Government Services											38.4*	38.4
Total Purchases**	77.2	3.5	140.98	8.4	28.1	93.12	29.4	9.6	3.1	11.7	49.9	455
Intermediate Imports	13.3	1.0	33.78	.9		9						57.98
Consumption Imports						50.22						50.22
Capital Goods Imports	2	.41	6.24	1.8	0.8	4.25	11.7				.8	28
Government (Taxes)	5.153	.478	41.877	.697	.95	66.539	4.35	0.5	0.2			120.744
Compensation of Employees	170.9	2.2	29.2	14.6	23.2	47.3	31.9	5	2.7	10.8	95.7	433.5
Operating Surplus	158.7	.8	18.5	1.4	6.3	59.9	21.4	28.2	12.4			307.6
Fixed Capital Consumption	12.6	.4	6.8	1.5	1.0	.7	7.5	15.3	0.2	0.7	9.1	55.8
VALUE ADDED	347.353	3.878	96.377	18.197	31.45	174.439	65.15	49	15.5	11.5	104.8	917.644
Total Inputs	426.553	7.788	243.597	28.397	60.35	271.809	106.25	58.6	18.6	23.2	155.5	1400.644

* Exogenous values

** Includes intermediate and consumption imports

Final Demand

House-hold Consum.	Govern. Consum.	Household Capital Formation	Govern. Capital Form.	Stocks	Exports	Total Final Demand	Total Output
188	3.2	11.1	1.3	-2.3	131.2	332.5	426.663
3.5				.4	.5	4.4	7.788
70	.8	11.7	15	4	16	117.5	243.597
13	.6			.5		14.1	28.397
12	1.644	20.7	16	2		52.344	60.35
200	1.0			5.5	2	208.5	271.809
20.6	3.0	14.5	4.5		1.3	43.9	106.25
10.2	3.0				.3	13.5	58.6
18.6						18.6	18.6
23.2						23.2	23.2
51.9	64.9		.4	- .1		117.1	155.5
611	78.144	58	37.2	10	151.3	945.644	1400.644

19.289

APPENDIX VI

Validated 1972/73
input-output table

Intermediate flow and primary inputs (LS Million)

	1 Agr.	2 Min.	3 Manuf.	4 E & W	5 Constr.	6 Commerce	7 Trans.	8 Finance	9 Commu.	10 PNP	11 Govt.	Total Interm. Demand
1) Agriculture	3.468		79.343		2.576	.413	.089				6.7*	92.589
2) Mining			3.597		1.791							5.338
3) Manufacturing	19.605				17.927	68.992	19.842	3.441	1.889		.4*	132.097
4) Electricity & Water	.099		2.549			2.788	.480	1.064	.251	6.270	.5*	14
5) Building & Construction								12.606			.4*	13.006
6) Commerce	5.18	.507	36.069	5.031	3.886	1.957		1.911	.630	.598	1.5*	57.27
7) Transport	48.848	2.993	12.262	2.899	1.404	1.935		.811	.33	.470	2*	73.95
8) Finance Services			7.16	.469	.515	17.035	15.589	.169		4.362		45.3
9) Community Services												0
10) PNP Services												0
11) Government Services											38.4*	38.4
Total Purchases**	77.2	3.5	140.98	8.4	28.1	93.12	36	20	3.1	11.7	49.9	472
Intermediate Imports	13.3	1.0	33.78	.9		9						57.98
Consumption Imports						50.22						50.22
Capital Goods Imports	2	.41	6.24	1.8	0.8	4.25	11.7				.8	28
Government Taxes	2.6	.478	41.877	0.4	.95	60.5	4.35	0.5	0.2			111.855
Compansation of Employees	170.9	2.2	29.2	14.6	23.2	47.3	31.9	5	2.7	10.8	95.7	433.5
Operating Surplus	158.7	.8	18.5	1.4	6.3	59.9	21.4	17.8	12.4			297.2
Fixed Capital Consumption	12.6	.4	6.8	1.5	1.0	.7	7.5	15.3	0.2	0.7	9.1	55.8
VALUE ADDED	344.8	3.878	96.377	17.9	31.45	168.4	65.15	38.6	15.5	11.5	104.8	898.355
Total Inputs	424	7.788	243.597	28.1	60.35	265.77	112.85	58.6	18.6	23.2	155.5	1398.355

*Exogenous Values

** Includes intermediate and consumption imports

Final Demand.

House-Hold Consum.	Govt. Consum.	Household Capital Formation	Govt. Capital Formation	Stocks	Exports	Total Final Demand	Total Output
186.911	3.2	11.1	1.3	-2.3	131.2	331.441	424
1.5				.4	.5	2.4	7.788
64	.8	11.7	15	4	16	111.5	243.597
13	.6			.5		14.1	28.1
7	1.644	20.7	16	2		47.344	60.35
200	1.0			5.5	2	208.5	265.77
15.6	3.0	14.5	4.5		1.3	38.9	112.85
10	3.0				.3	13.3	58.6
18.6						18.6	18.6
23.2						23.2	23.2
51.9	64.9		.4	.1		117.1	155.5
591.711	78.144	58	37.2	10	151.3	926.355	1398.355

19.289

APPENDIX VII

The basic input-output table
(1972/73)

Intermediate flow and primary inputs. (LS Million)

	1 Agr.	2 Min.	3 Manuf.	4 E & W	5 Constr.	6 Commerce	7 Trans.	8 Finance	9 Commu.	10 PNP	11 Govt.	Total Interm. Demand
1) Agriculture	3.94		78.171		3.112	.552	.114				6.7*	92.589
2) Mining			3.345		2.043							5.388
3) Manufacturing	17.091		.5*	1.5*	16.615	70.810	19.629	3.641	1.91		0.4*	132.097
4) Electricity & Water	1.0*		10.0*	0.5*		.345	.057	.136	.031	1.431	0.5*	14.0
5) Building & Construction								12.606			0.4*	13.006
6) Commerce	5.463	.523	32.985	3.927	4.357	2.43	1.5*	2.446	.77	1.368	1.5*	57.27
7) Transport	49.706	2.977	10.82	2.184	1.519	2.318		1.001	.389	1.037	2.0*	73.95
8) Finance Services			5.159	.289	.455	16.664	14.7	.17		7.863		45.3
9) Community Services												0
10) PNP Services												0
11) Government Services											38.4*	38.4
Total Purchases	77.2	3.5	140.98	8.4	28.1	93.12	36	20	3.1	11.7	49.9	472
Intermediate Imports												
Consumption Imports												
Capital Goods Imports												
Government (Taxes)												
Compansation of Employees												
Operating Surplus												
Fixed Capital Consumption												
VALUE ADDED												
Total Inputs												

*Exogenous values

**Includes Intermediate and consumption imports

Final Demand.

House-Hold Consum.	Govt. Consum.	Household Capital Formation	Govt. Capital Formation	Stocks	Exports	Total Final Demand	Total Output
							424
							7.788
							243.597
							28.1
							60.35
							265.77
							112.85
							58.6
							18.6
							23.2
							155.5
							1398.355

APPENDIX VIII

1974/75 updated input-output table

Intermediate flow and primary inputs (LS Million)

	1 Agr.	2 Min.	3 Manuf.	4 E & W	5 Construc.	6 Commerce	7 Trans.	8 Finance	9 Comm.	10 PNP	11 Govt.	Total Interm. Demand
1) Agriculture	11.046		108.412		8.615	1.775	.215				9.2*	139.264
2) Mining			2.433		2.967							5.4
3) Manufacturing	27.753		.402	1.031	26.642	131.891	21.485	2.079	1.504		.09*	212.876
4) Electricity & Water	2.313		11.442	.489		.915	.089	.111	.035	1.242	1.7*	18.336
5) Building & Const.								37.157			.1*	37.257
6) Commerce	23.499	1.318	70.188	7.148	18.506	11.989	4.349	3.699	1.606	2.208	.08*	144.591
7) Transport	93.489	3.282	10.067	1.738	2.821	5.001		.662	.355	.732	.09*	119.046
8) Finance Services			8.232	.394	1.449	61.653	31.961	.193		9.518		113.4
9) Community Services												0
10) PNP Services												0
11) Government Services											53.03*	53.03
Total Purchases**	158.1	4.6	211.176	10.8	61.0	213.224	58.1	43.901	3.5	13.7	65.1	843.2
Intermediate Imports	29.4	2.0	61.476	1.0		20.0						113.876
Consumption Imports						134.324						134.324
Capital Goods Imports	4.7	1.0	13.6	3.353	3.089	5.095	36		0.1		1.063	68
Government (Taxes)	10.484	.3	60.0	.983	1.968	102.775	9.946	.9	.225		-2.036	185.545
Compansation of Employees	317.1	3.0	30.2	16.1	51.2	85.1	43.2	7.8	2.8	12.2	139.3	708.0
Operating Surplus	236.6	1.4	48.9	3.8	10.6	128.0	34.1	41.8	13.5			518.7
Fixed Capital Consumption	26.4	.2	16.6	1.0	2.0	1.0	11.1	41.9	0.3	.7	14.2	115.4
VALUE ADDED	590.584	4.9	155.7	21.883	65.768	316.875	98.346	92.4	16.825	12.9	151.464	1527.645
Total Inputs	753.384	10.5	380.476	36.036	129.857	535.194	192.446	136.3	20.425	26.6	217.627	2438.845

*Exogenous Values

**Includes intermediate and consumption imports

Final Demand

House-hold Consum.	Govt. Consump.	Household Capital Formation	Govt. Capital Formation	Stocks	Exports	Total Final Demand	Total Output
435.72		10.6	7.1	15.7	145	614.12	753.384
4				.4	.7	5.1	10.5
80	1	22.1	43.5	2	19	167.6	380.476
16.8	.4			.5		17.7	36.036
10.4	1	18.4	60.4	2.4		92.6	129.857
350	1.903			23.8	14.9	390.603	535.194
20.5	.6	30.8	17.8		3.7	73.4	192.446
22.7					0.2	22.9	136.3
20.425						20.425	20.425
26.6						266	26.6
100	55.097		3.7	5.8		164.597	217.627
1087.145	60	81.9	132.5	50.6	183.5	1595.645	2438.845

CHAPTER V

MULTIPLE OBJECTIVE PLANNING MODELS FOR SUDAN

1. INTRODUCTION

Development plans for Sudan are characterized by a multiplicity of objectives just as with many other developing countries. The three development plans so far formulated have five, seven, and sixteen objectives respectively.

Some quantitative economic models are known to enhance the decision process greatly, and when applied to development plans they lead to the checking of the consistency of the plan and the feasibility of the targets set and thus assist in policy making. In addition to feasibility, optimality planning will indicate the maximum value an objective or a preference function will take given the available resources and the existing economic structure. This chapter, however, will consider preferred-solution planning rather than optimality planning since the planning problem is of a multiple objective rather than a single objective nature, and hence calls for a best solution rather than an optimal solution.

In most of the literature, whether concerning single objective or multiple objective development planning, usually one model is used, for example, Yoon [18], Masud [12], Tantusuth [15], Joe [8], etc. This paper, however, will approach the development planning through two multiple objective models. The first is a Terminal Year model (TY) while the second is a Year by Year model (YBY). The TY model is to serve as a perspective planning tool while the YBY model is to serve as a detailing and an implementing tool. Although the utilization of the TY model precedes that of the YBY model, its construction will follow that of the YBY as will be shown in the next few pages.

Two MODM methods are used to solve these models, the STEM method and a modified version of the Method of Satisfactory Goals. The solutions of the two models by each method are compared and a final evaluation of the two MODM methods is made. Finally, conclusions and suggestions for future extensions are presented.

2. MODM MODELS FOR SUDAN

Dynamic input-output models incorporate an accelerator-type investment theory in which demands for investment depend on future growth of output, i.e., investment is treated as endogenous to the model. Optimization of these dynamic models by linear programming has found many applications, for example, the models for India by Eckaus and Parkin [5]. Their optimality planning models were used in some studies like that by Joe [8] for economic planning in Korea. The models incorporated many features of developing economices and also include gestation lags instead of the simple accelerator relationship in the Leontief dynamic model. However, they require a lot of information which for some countries might not be available.

For Tunisia, Martens and Pindyck [11] used an aggregated modified version of a large simulation model which was developed as a planning tool for Tunisia's Ministry of Planning. The model aggregates the economy into five sectors and contains 68 variables, of which 47 are endogenous. Instead of linear or non-linear programming they used optimal control theory. The study, however, is to demonstrate that linear-quadratic optimal control can be applied to long-term multisectoral planning, and they considered only the problem of investment allocations between sectors over time.

2.1 The Year By Year MODM Model for Sudan

In spite of the fact that a number of optimization planning models were surveyed, for both developed and developing countries, the preferred-solution planning model for Sudan is constructed so as to conform with the 6-year plan (1977/78-1982/83). This has three objectives: the first is to test the model with some real data, the second is to check the 6-year plan itself, and the third is to demonstrate its practicality and applicability for future planning.

2.1.1 The Structure of the Model

The model breaks the economy into 11 sectors to comply with the input-output table developed for Sudan in Chapter 4. It consists of 38 variables, of which 34 are endogenous and 4 are exogeneous.

List of Endogenous variables:

$X(t)$ = column vector of gross output of each sector

$C(t)$ = total private consumption

$\Delta L(t)$ = increase in wages (employment)

$N(t)$ = new total fixed investment

$Z(t)$ = column vector of additional capacities for each sector

$S(t)$ = total domestic savings

$DF(t)$ = deficit finance

$\nu(t)$ = annual rate of inflation

$GDP(t)$ = gross domestic product - in real terms

$Y(t)$ = a vector of the shares of the sector in GDP in real terms

$M_1(t)$ = total raw materials imports

$M_2(t)$ = total consumer goods imports

$M_3(t)$ = total imports of capital goods

$M(t)$ = total annual imports.

Exogeneous Variables

$W(t)$ = increase in stock

$G(t)$ = government consumption

$E(t)$ = exports of goods and services

$F(t)$ = foreign loans

Parameters

I = n x n identity matrix

A = n x n matrix of technical coefficients

P = n x n capital coefficients matrix

w = a vector of stocks distribution (n)

g = a vector of government consumption distribution (excluding services)

c = a vector of private consumption distribution (n)

e = a vector of export distribution (n)

b = a vector of incremental capital/output ratios (ICOR) (n)

r = planned rate of growth of real income

T = income velocity of money

$\beta(t)$ = percentage of GDP as domestic savings

α = a vector of boundary values for the proportions of sectors in GDP (n)

m_1 = a vector of raw material imports coefficients (n)

m_2 = a vector of consumer goods imports coefficients (n)

m_3 = a vector of capital goods imports coefficients (n)

k = a vector of the ratios of foreign exchange in ICOR

a. Production constraints

These show the relations between the supply and demand sides for each sector. The supply side consists of the gross output, where the latter includes both domestic and imported goods. Both raw materials and consumer goods imports are included in the intermediate input since they usually flow through the different sectors for a developing economy. The demand side consists of requirements for goods as intermediate input, and for final demands which include those for inventory, private and government consumption, export, and for new capacity. In equation form:

$$AX(t) + W(t)\ w + C(t)\ c + G(t)\ g + E(t)\ e + Z(t) \leq X(t) \qquad (1)$$

Equation (1) is based on the assumptions that the technical coefficients, matrix A, remain stationary over time and that there are no excess capacities in the sectors.

a_1 Intermediate Input:

$$AX(t) = [x_{ij}(t)], \qquad t = 1,2,\ldots,T \tag{2}$$

This is the standard Leontief relation where x_{ij} is the output of sector i going as an input into sector j in year t.

a_2 Increase in stock:

$$W(t)\ w = \bar{W}(t)\ w \tag{3}*$$

a_3 Government Consumption:

$$G(t)\ g = \bar{G}(t)\ g \tag{4}*$$

a_4 Exports:

$$E(t)\ e = \bar{E}(t)\ e \tag{5}*$$

a_5 New Capacity Added

$$Z(t) = P[X(t) - X(t-1)] \tag{6}$$

where P is an n x n capital coefficient matrix, and p_{ij} represents the required input from sector i to provide one unit of new capacity for sector j. Equation (6) assumes that the addition of new capacity is instantaneous; this is to make the model conform to the six-year plan.

b. Private Consumption Constraint:

$$C(t) \geq C(t-1), \qquad t = 1,2,\ldots,T \tag{7}$$

$$C(0) = \overline{C(0)} \tag{8}$$

* $\bar{W}(t)$, $\overline{G(t)}$, $\overline{E(t)}$, determined outside the model.

Instead of incorporating a minimum rate of growth as in other models, the constraint requires that consumption of the current year should be greater than that of the previous year, since C(t) is one of the objectives and its rate of growth is implicitly conceived by the decision maker (DM) in his trade-offs between objectives.

c. Total Capital Investment

$$N(t) + W(t) \leq M_3(t) + S(t) + DF(t) \tag{9}$$

The planning process for developing countries in general and for Sudan specifically requires an explicit statement of the amount of capital to be invested each year and the sources of this capital. Constraint (9) has the feature of being unbounded, i.e., the right hand side can increase indefinitely; however, other constraints will limit this unboundedness.

c1. Annual Fixed Capital Investment:

$$N(t) = b' [X(t) - X(t - 1)] \tag{10}$$

Annual fixed capital investment is assumed to include replacement investments.

c2. Domestic Saving:

$$S(t) = \beta(t)\ GDP(t) \tag{11}$$

Domestic saving is expressed in terms of GDP to comply with the 6-year plan, while the equality constraint is to force the model to rely on domestic saving before running to deficit finance.

c3. Deficit Finance:

$$DF(t) \leq \frac{1}{T}\{GDP(t)[1 + \nu(t)] - GDP(t - 1)\} \tag{12}$$

By assuming a constant annual rate of real income growth, r, equation (12) can be written as:

$$DF(t) \leq \frac{1}{T} GDP(0)(1 + r)^{t-1} [\nu(t) + r + r\nu(t)] \tag{13}$$

Equations (12) and (13) are the Cambridge equations of quantity of money. More information about deficit finance and these equations can be found in [13, p. 83].

d. Balance of Payments Constraint:

$$M_1(t) + M_2(t) + M_3(t) \leq E(t) + F(t) \tag{14}$$

d1. Raw Materials Imports:

$$M_1(t) = m_1' X(t) \tag{15}$$

d2. Consumer Goods Imports:

$$M_2(t) = m_2' X(t) \tag{16}$$

Consumer goods imports are determined endogenously rather than exogenously because the classification of imports of the Sudan [4] for this category incorporates goods which might be considered as inputs for some sectors.

d3. Capital Goods Imports:

$$M_3(t) = k'\hat{b}[X(t) - X(t - 1)] \tag{17}$$

where $\hat{b}$ is an n x n matrix whose diagonal element is the vector b; $k'\hat{b}$ can be termed the "Foreign Incremental Capital-Output Ratio."

d4. Foreign Loans:

$$F(t) = \overline{F(t)} + \Delta F(t - 1) \tag{18}$$

where $\overline{F(t)}$ is the given value of the foreign loans for year t and $\Delta F(t - 1)$ represents the remaining or unused foreign loans in the previous year, while it is assumed the $\Delta f(0) = 0$.

e. Employment Constraint:

$$\Delta L(t) = \ell' [X(t) - X(t - 1)] \tag{19}$$

This relation is usually derived from the Leontief input-output tables; however, it does not give a good reflection of the employment level in each sector for a developing country due to substantial differences in wages [14].

f. Value Added by Each Sector:

$$Y(t) = (I - A' - \hat{m}_3) X(t) \tag{20}$$

where $\hat{m}_3$ is an n x n matrix whose diagonal element is the vector m_3.

g. Gross Domestic Product (GDP):

$$\begin{aligned} GDP(t) &= i' Y(t) \\ &= i' (I - A' - \hat{m}_3) X(t) \end{aligned} \tag{21}$$

where i is a unit vector for summation.

h. Sectoral Growth Constraints:

$$Y(t) \gtreqless GDP(t)\ \alpha \qquad (22)$$

The vector of boundary values, α, is to control the growth of sectors so that some sectors are not expanded beyond acceptable limits at the expense of other sectors during the preferred solution planning process. It will also aid in complying with the six-year plan policy of raising or lowering the shares of some sectors to some percentage of GDP. A summary of the YBY model, after substitutions, is shown in Table 1.

Table 1. A Summary of the YBY Model (After Substitutions)

---

a) Objectives

1. Gross Domestic Product

$$\text{Max GDP}(t) = i'(I - A' - \hat{m}_3) X(t)$$

2. Increase in Employment

$$\text{Max } \Delta L(t) = \ell'[X(t) - X(t-1)]$$

3. Inflation

$$\text{Min } \nu(t)$$

4. Private Consumption

$$\text{Max } C(t)$$

b) Constraints

1. Production

$$AX(t) + W(t)w + C(t)c + G(t)g + E(t)e + P[X(t) - X(t-1)] \leq X(t)$$

2. Private Consumption

$$C(t) \geq C(t-1)$$

3. Total Capital Investment

$$b'[X(t) - X(t-1)] + W(t) \leq k'\hat{b}[X(t) - X(t-1)] + \beta(t)i'(I-A'-\hat{m}_3)X(t) + DF(t)$$

4. Deficit Finance

$$DF(t) \leq \frac{1}{T} GDP(0)(1+\nu)^{t-1} [\nu(t) + r + r\nu(t)]$$

5. Balance of Payments

$$m_1'X(t) + m_2'X(t) + k'\hat{b}[X(t) - X(t-1)] \leq E(t) + [\bar{F}(t) + \Delta F(t-1)]$$

6. Sectoral Growth

$$(I-A'-\hat{m}_3) X(t) \gtreqless i'(I-A'-\hat{m}_3) X(t) \alpha$$

2.2 The Terminal Year MODM Model for Sudan

The annual model has the disadvantage that it requires the specification of a complete set of variables for each time period, i.e.,the model is highly disaggregated both by sector and by time period,leading to a large number of variables. For the development planning process it is more suitable to start with a terminal year model (TY), that is, to find the terminal year values of the objectives and other variables given the initial or base year values and the constraints.

Manne [10] developed a consistency model to cover the planning period; he termed it the 'dynamic inverse'. He used the accelerated principle to develop the relation between the initial output vector and the post terminal year output vector in terms of the technical coefficients and the capital coefficients matrices, and the final demand vector. His model could be used to construct a rolling plan or for consistency check on a tentative plan or for a check on the data to be used in a dynamic input-output model.

The structure of the terminal year preferred solution planning model for Sudan is as follows:

a. Production Constraints:

$$HX(T) + \sum_{t=1}^{T} (PH^{-1})^{T-t} [W(t)\, w + C(t)\, c + G(t)\, g + E(t)\, e]$$

$$\leq (PH^{-1})^{T-1} PX(0) \qquad (23)$$

where H is n x n matrix = (A + P - I). Appendix 1 shows how the equation is derived.

b. Private Consumption Constraint

Assuming a uniform annual rate of private consumption growth, equation (7) can be written as:

$$C(t) \geq C(0)\ [1 + \rho]^{t} \tag{24}$$

Equation (24) can be approximated by the following linear relation (see Appendix 2 for its development):

$$C(t) \geq C(0)\ [1 + t\ \rho] \tag{25}$$

c. Total Capital Investment:

$$N + W \leq M_3 + S + DF \tag{26}$$

c1. Total Fixed Capital Investment:

$$N = \sum_{t=1}^{T} N(t) = b'[X(T) - X(0)] \tag{27}$$

c2. Domestic Saving

$$S = \bar{\beta}\ GDP \tag{28}$$

where $\bar{\beta}$ is the average proportion of gross domestic produce (GDP) for the whole period as a domestic saving. For the derivation of GDP see Appendix 3 .

c3. Deficit Finance:

$$DF \leq \frac{1}{T}\ GDP(0)\ [R + \nu + R_{\nu}] \tag{29}$$

where R $(=(1+\gamma)^T-1)$ is the effective rate of growth for the plan period.

d. Balance of Payments Constraint:

$$M_1 + M_2 + M_3 \leq E + F \tag{30}$$

d1. Raw Materials Imports:

$$M_1 = m_1' \{(A-I)^{-1}[PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\} \tag{31}$$

where

$$Q(t) = [W(t)w + C(t)c + G(t)g + E(t)e] \tag{32}$$

$$H = (A+P-I)$$

Appendix 3 shows how equation (31) is derived.

d2. Consumer Goods Imports:

$$M_2 = m_2' \{(A-I)^{-1}[PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\} \tag{33}$$

Same comments as d1.

d3. Capital Goods Imports:

$$M_3 = k'\hat{b} \sum_{t=1}^{T} [X(t) - X(t-1)]$$

$$= k'\hat{b} [X(T) - X(0)] \tag{34}$$

d4. Foreign Loans:

$$F = \sum_{t=1}^{T} F(t) \tag{35}$$

e. Employment Constraint:

$$\Delta L = \ell' \sum_{t=1}^{T} [X(t) - X(t-1)]$$

$$= \ell' [X(T) - X(0)] \tag{36}$$

f. Value Added by Each Sector:

$$Y(T) = (I-A'-\hat{m}_3)\ X\ (T) \tag{37}$$

g. Gross Domestic Product:

For the terminal year:

$$GDP(T) = i'\ Y(T) = i'\ (I-A'-\hat{m}_3)\ X\ (T) \tag{38}$$

For the whole plan period:

$$GDP = i'\ (I-A'-\hat{m}_3)\ \{(A-I)^{-1}[PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\} \tag{39}$$

where H and Q(t) are as defined in d_1. See Appendix 3 for the derivation of equation (39).

h. Sectoral Growth Constraints:

$$Y(T) \gtreqless GDP(T)\alpha \tag{40}$$

A summary of the TY model is shown in Table 2.

3. OBJECTIVES FOR THE PERIOD BY PERIOD MODEL:

1. Gross Domestic Product:

This is one of the most common objectives in development planning, whether for developed or developing countries. It may take the form of the rate of growth of GDP or the rate of growth of per capita income when population growth is taken into consideration. When using input-output models, it can be determined either from the supply side, summation of value added by each sector, or from the demand side by the summation of final demand minus imports. For this study it is considered from the input side so that

$$GDP\ (t) = i'\ (I-A'-\hat{m}_3)\ X(t)$$

where i' is the transpose of a unit vector for summation, and A' is the transpose of matrix A.

Recent trends, however, do not consider the growth of GDP by itself as an indicator of development and economic well-being, especially for developing

Table 2. A summary of the TY MODEL

---

a) Objectives

1. Gross Domestic Product

$$\text{Max } GDP(T) = i' (I - A' - \hat{m}_3) X(T)$$

2. Increase In Employment

$$\text{Max } \Delta L = \ell'[X(T) - X(o)]$$

3. Inflation

$$\text{Min } \nu$$

4. Private Consumption

$$\text{Max } \rho$$

b) Constraints

1. Production

$$HX(T) + \sum_{t=1}^{T} (PH^{-1})^{T-t}[W(t)w + C(t)c + G(t)g + E(t)e] \leq (PH^{-1})^{T-1} PX(o)$$

2. Private Consumption

$$C(t) \geq C(o)\ [1 + t\rho]$$

3. Total Capital Investment

$$N + W \leq M_3 + S + DF$$

$$3.1 \quad N = b'[X(T) - X(o)]$$

$$3.2 \quad W = \sum_{t=1}^{T} W(t)$$

$$3.3 \quad M_3 = n'\hat{b}[X(T) - X(o)]$$

$$3.4 \quad S = \bar{\beta}(GDP)$$

4. Deficit Finance

$$DT \leq \frac{1}{T} GDP(o)\ [R + \nu + R\nu]$$

Table 2. (continued)

5. Balance of Payments

$$M_1 + M_2 + M_3 \leq E + F$$

$$5.1 \quad M_1 = m_1' \{(A-I)^{-1} [PX(o) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\}$$

$$5.2 \quad M_2 = m_2' \{(A-I)^{-1} [PX(o) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\}$$

$$5.3 \quad E = \sum_{t=1}^{T} E(t)$$

$$5.4 \quad F = \sum_{t=1}^{T} F(t)$$

6. Sectoral Growth

$$(I - A' - \hat{m}_3) X(T) \gtreqless GDP(T)\ \alpha$$

$$6.1 \quad GDP(T) = i' (I-A'-\hat{m}_3) X(T)$$

7. Gross Domestic Product For Plan Period

$$GDP = i'(I-A'-\hat{m}_3)\{(A-I)^{-1} [PX(o) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\}$$

$$7.1 \quad Q(t) = [W(t)\ w + C(t)c + G(t)g + E(t)e]$$

$$7.2 \quad H = (A + P - I)$$

countries, unless equality of income distribution is considered. This study will consider GDP only as one of its objectives, i.e.,

$$\text{Max} \quad GDP\ (t) \tag{41}$$

2. Increase in Employment:

Increase in employment in each of the sectors is assumed to be proportional to the output of each sector, i.e.,

$$\Delta L = \ell' \left[X(t) - X\ (t-1)\right] \tag{42}$$

The same comments on constraint (19) are applicable here; if the average wages for each sector are available better results might be obtained; however, for this paper the second objective is:

$$\text{Max} \quad \Delta L\ (t) \tag{42}$$

3. Rate of Inflation:

The principal inflation theories are classified by economists as demand-pull theories or cost-push theories. Demand-pull inflation is the rise in price levels because demand for goods and services exceeds the supply available at existing prices. Demand-pull inflation is thus related to money supply as can be found in economic books and the theories behind it. In this study, however, the objective is to minimize inflation, ν, resulting from inflationary-financed growth. Thus the third objective is:

$$\text{Min} \quad \nu\ (t) \tag{43}$$

4. Private Consumption.

Instead of expressing private consumption in the form of a behavioral relation, it is considered an endogenous variable in the production function of equation (1) and constrained so as to ensure that it is greater than the previous year

without specifying a minimum growth rate, since the DM in the interactive solution process will automatically build his trade-offs on some rate of growth for private consumption. Therefore the last objective is:

$$\text{Max } C(t) \tag{44}$$

4. OBJECTIVES FOR THE TERMINAL YEAR MODEL:

1. Gross Domestic Product

The objective here is to maximize the terminal year, T, Gross Domestic Product, i.e.,

$$\text{Max } GDP(T) \tag{45}$$

2. Increase in Employment:

The objective is to maximize the increase in employment for the whole plan period, i.e.,

$$\text{Max } \Delta L \tag{46}$$

3. Rate of Inflation:

The objective is:

$$\text{Min } \nu \tag{47}$$

4. Private Consumption Growth

$$\text{Max } \rho \tag{48}$$

5. DATA FOR SUDAN

The data for this study is mainly from the 6-year plan [2], although some adapted data from other countries is used. The input-output table of Chapter IV is the backbone for the two models. It should be noted that even the 6-year plan was prepared in the absence of the final national accounting data for the preceding three years, as mentioned in Chapter III. The 6-year plan also

incorporates some conflicting and not clearly stated figures; however, some educated guesses and simple assumptions successfully resolved the problem of data.

5.1 Sector Classification

The sectoral classification of the economy is shown in Table 3, which is in accordance with the input-output table developed for Sudan in the preceding chapter. The actual plan, however, aggregates some of these sectors into one sector.

5.2 The Base Year Data

The base year data (1976/77) for some of the endogenous variables is shown in Table 4. The values for X were computed from the relation:

$$X(O) = GDP\ (O)\ [i'(I-A' - \hat{m}_3)]^{-1}$$

5.3 Exogenous Values

The values of these variables are from the 6-year plan. The stock of inventory is given by the plan as a lump sum of LS 240 million; it is consequently assumed that the stock buildup is at the same annual rate as the "Gross Capital Formation", 12.1%, and hence the annual values of stock are computed as shown in Table 5 with the other given values.

5.4 Parameter Values

Parameter values for these models are from three sources: those given in the plan, from the developed input-output model of Chapter IV, and values borrowed or adapted from other sources and countries. Those belonging to the first source are the planned rate of growth of real income, r, the percentage of GDP as domestic savings, $\beta(t)$, and the vector of boundary values for the proportions of sectors in GDP, α. The matrix of technical coefficients, A, imports coefficients (m_1, m_2, m_3), and the vectors of sectoral share of final aggregate demand for stock, w, government consumption, g, and export, e,

Table 3. Sector classification

Aggregated Sector	Included Sectors
1. Agriculture	Agriculture, Livestock, Hunting, Forestry and Fishing
2. Mining	Mining and Quarrying
3. Manufacturing	Manufacturing and Handicrafts
4. Electricity and Water	Electricity and Water
5. Building and Construction	Building and Construction
6. Commerce	Commerce, Restaurants, Hotels, Bars, etc.
7. Transport	Transport, Storage and Communication
8. Finance Services	Finance, Insurance, Real Estate and Business Services
9. Community Services	Community, Social and Personal Service
10. Private Nonprofit Services	Social, Recreational and Related Community Services
11. Government Services	Economic, Community, Administrative, Social and Personal Services

Table 4. Base year (1976/77) data
(Rounded to the nearest integer)

Variable	Value in LS Million
$X_1(0)$	899
$X_2(0)$	12
$X_3(0)$	454
$X_4(0)$	43
$X_5(0)$	155
$X_6(0)$	638
$X_7(0)$	230
$X_8(0)$	163
$X_9(0)$	24
$X_{10}(0)$	32
$X_{11}(0)$	259
GDP(0)	1822
C(0)	1412

Table 5. Values of exogenous variables (LS Million)

Variable	Year						Plan Total
	1	2	3	4	5	6	
W(t)	30	33	37	42	46	52	240
G(t)	272	289	308	328	349	372	1918
E(r)	238	264	293	325	361	400	1881
F(t)	178	193	210	228	248	270	1327

are those obtained from the input-output model. It is assumed that the distribution of these aggregate values will be in the same constant pattern as the base year and will continue through the plan. Although this might be an oversimplification for the actually intended shares, it is adopted due to the lack of detailed data. The values for the above mentioned parameters are shown in Tables 6 through 8. Values for the matrix of capital coefficients are obtained by adapting those used by Eckaus and Perkin [5, p. 67] in their models for the third plan of India. For the incremental capital-output ratio again the values for India and Eygpt [1, 5] were adjusted to resemble the conditions of take-off for the economy; for the producers of government services sector a value of 1.76 is used compared to a high vlaue of 2.15 [3, p.44] obtained more than twenty years ago.

The 6-year plan calls for a rise in gross domestic savings from 8.5% of GDP in the base year to 13% in the terminal year.

Income velocity of money for this study is computed from the relation:

$$T = \frac{1}{\frac{M_2}{GDP}} \tag{50}$$

where M_2 is the broader definition of the growth of money supply. The value of M_2 used here is for 1974 [9, p. 87]:

$$M_2 = 92.75 + 107.69 + 39.15 = 238.59$$

while GDP (1974/75) is LS 1511 million.

$$T = \frac{1511}{238.59} = 6.333$$

Table 6. Input-output coefficients (A)

Sector	1	2	3	4	5	6	7	8	9	10	11
1	.014662	0	.284938	0	.066342	.003317	.001117	0	0	0	.042274
2	0	0	.006395	0	.022848	0	0	0	0	0	0
3	.036838	0	.001057	.028610	.205164	.246436	.111642	.015253	.073635	0	.000414
4	.003070	0	.030073	.013570	0	.001710	.000462	.000814	.001714	.046692	.007812
5	0	0	0	0	0	0	0	.272612	0	0	.000460
6	.031191	.125524	.184474	.198357	.142511	.022401	.022599	.027139	.078629	.083007	.000368
7	.124092	.312571	.026459	.048230	.021724	.009344	0	.004857	.017381	.027519	.000414
8	0	0	.021636	.010934	.011158	.115197	.166078	.001416	0	.357820	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	.243674

Table 7. Capital coefficients (P).

Sector	1	2	3	4	5	6	7	8	9	10	11
1	0	0	0	0	0	0	0	0	0	0	0
2	.001	0	.002	0	.006	0	.001	0	0	0	0
3	.136	.496	.510	.404	.498	.300	.884	.005	.310	.315	.300
4	0	0	0	0	0	0	0	0	0	0	0
5	.798	.441	.410	.543	.256	.539	.090	.895	.639	.600	.500
6	.060	.050	.060	.035	.170	.100	.010	.100	.042	.070	.090
7	.004	.014	.015	.018	.070	.061	.015	0	.009	.005	.010
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	.001	0	.001	0	0	0	0	0	0	0	0
11	0	0	.002	0	0	0	0	0	0	.01	.100

Table 8. Values of parameter vectors

Sector	w	g	c	e	m_1	m_2	m_3	b	k
1	.3103	0	.372	.7902	.0390	0	.0062	1.63	.4
2	.0079	0	.0034	.0038	.1905	0	.0952	2.45	.42
3	.0395	.0048	.0683	.1035	.1616	0	.0357	2.2	.52
4	.0099	.0019	.0143	0	.0277	0	.0930	5.3	.65
5	.0474	.0048	.0089	0	0	0	.0238	.4	.12
6	.4703	.0091	.2990	.0812	.0374	.2510	.0095	.18	.05
7	0	.0029	.0175	.0202	0	0	.1871	4.9	.51
8	0	0	.0194	.0011	0	0	0	8.2	.05
9	0	0	.0174	0	0	0	.0049	.16	.06
10	0	0	.0227	0	0	0	0	1.6	.37
11	.1146	.2650	.0854	0	0	0	.0049	1.76	.24

or money supply in circulation is 15.8% of GDP.

The plan gives values for structural changes as shown in Table 9; in this study some flexibility is given to this policy by bounding some of the sectors as presented in Table 10.

6. RESULTS AND DISCUSSION

1. The Year by Year Model

The model contains 31 endogenous or decision variables and 36 rows. It is to be solved period by period for six periods (six years), the relation thus being recursive where some of the objectives and constraints depend on the solution variables of the preceding period. Such a model could be reduced to a standard linear programming by using timed variables for each time period. However, this would lead to a large number of variables and the model would become computationally hard to manage; also, the sequential nature of the MODM process would be lost.

1.1 The STEM Method

1.1.1 Details of STEM Solution Steps

The STEP-method (STEM) is appropriately used in the absence of an a priori definition of what is the best compromise between the conflicting objectives of a MODM linear programming problem and when the decision maker is much involved in the solution process. STEM is an iterative procedure which involves a sequential exploration of solutions follwoing these steps:

Step 0: Construction of pay-off table:

In this step each objective is maximized (or minimized) in turn subject to the set of constraints. The optimal value for each objective is the "ideal solution". For each of the optimization problems the values of the remaining objectives, beside the ideal solution, are also computed. This will give a

Table 9. Planned growth rates and sectoral changes (%)

Sectors	1976/77 %	1982/83 %	Annual Growth Rate %
Agriculture	39	37	6.5
Manufacturing & Mining	9	10	9.5
Electricity & Water	1	1	8.0
Construction	4	5	9.0
Transportation	6	6	7.5
Commerce, Finance & Real Estate	24	24	8.0
Government & other services	11	11	7.5
GDP at MP	100	100	7.5

Source: [2]

Table 10. Sectoral bounds (% of GDP)

Sector	Lower-Limit	Upper-limit
1. Agriculture	0	∞
2. Mining	0	∞
3. Manufacturing	10%	∞
4. Electricity and Water	0	∞
5. Building and Construction	4.5%	∞
6. Commerce	0	∞
7. Transport	6%	∞
8. Finance Services	0	∞
9. Community Services	0	∞
10. Private and Non-Profit Services	0	∞
11. Government Services	0	10%

square matrix of the values taken by the objectives where the diagonal represents the ideal solution. The rows of this matrix are the values taken by the n objectives in each of the solutions. The columns of this matrix show the maximum and the minimum values each objective, and hence the range, can take given the set of constraints.

Step 1: Calculation Phase:

In this step weights (π_j, j = 1,2,...,n) which are to give the relative importance of the distances to the optima are calculated. The following linear programming at the m^{th} cycle is then solved.

$$\begin{aligned} &\min \quad \lambda \\ &\text{s.t.} \quad \lambda \geq [f_j^* - f_j(\underline{x})]\,\pi_j, \quad j = 1,2,\ldots,n \\ &\qquad \underline{x} \in x^m \\ &\qquad \lambda \geq 0 \end{aligned} \tag{51}$$

The problem above is to find a feasible solution which is the "nearest", in the MINIMAX sense, to the ideal solution f_j^*. For more information about this step and the necessary calculation see Hwang and Masud [6, pp. 171-173].

Step 2: Decision Phase:

The values of the objectives, vector $\underline{f}^m$, are then presented to the decision maker (DM) who is to compare them to the vector of the ideal solution $\underline{f}^*$. The DM is then to look for those objectives which are satisfactory and to indicate by how much, Δf_i, these satisfactory objectives can be relaxed in order to improve the remaining ones or those which are considered unsatisfactory. In the next iteration the problem is formulated:

$$\begin{aligned} &\min \quad \lambda \\ &\text{s.t.} \quad \lambda \geq [f_j^* - f_j(x)]\pi_j && j \neq i,\ j = 1,2,\ldots,n \\ &\qquad f_i \geq f_i^m - \Delta f_i && i = 1,2,\ldots,n \end{aligned}$$

$$f_j \geq f_j^m \qquad j \neq i,\ j = 1,2,\ldots,n$$

$$\underline{x} \in x^m$$

$$\lambda \geq 0 \qquad (52)$$

The weight(s) π_i are set to zero and the calculation phase of cycle m + 1 starts.

The final solution is obtained when all the objectives are satisfactory, If none of the objectives is satisfactory then there is no solution to the problem. Sensitivity analysis can also be conducted to show the behavior of the different objectives during any cycle, thus reflecting to the DM the trade-offs between the objectives.

1.1.2 Solution

All the problems, which are linear programming problems, in this study are solved by IBM Mathmatical Programming Systems/360 (MPS/360).

Following the conventional optimization or multiple objective solution method for this development planning problem will yield a pay-off table as shown in Table 11 which is for year one of the plan. What is meant by conventional is that in most of the literature surveyed on the optimization of multisectoral development planning problems no trace of control is kept on the growth of the individual sectors during the optimization process. From Table 11 it can be observed that two values of the first objective, GDP, are below that of the base year (=1822), also two cells of the second objective, ΔL, are zero. Finally, the rate of inflation is zero for all the cells. Observing the sectoral contribution to GDP for each of the ideal solutions, Table 12, one would find the answer from the wide and illogical variation of these percentages, which is attributed to the fact that the sectors of the economy are allowed to grow without constraining their growth within some

Table 11. Pay-off table for year 1 - without sectoral constraints.*

	GDP(1)	ΔL(1)	ν(1)	C(1)
GDP(1)	2053	82	0	1412
ΔL(1)	1886	166	0	1412
ν(1)	1607	0	0	1481
C(1)	1734	0	0	1673

*GDP(t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 12. Year 1: sectoral % shares in GDP- without sectoral constraints

	Sector	Objective *			
		Max GDP(1)	Max ΔL(1)	Min ν(1)	Max C(1)
1)	Agriculture	35.35%	35.18%	37.96%	40.49%
2)	Mining	0.37%	0.22%	0.12%	0.19%
3)	Manufacturing	11.11%	5.96%	0.0 %	3.83%
4)	Electricity & Water	1.37%	4.16%	10.31%	6.51%
5)	Building & Construction	6.41%	2.46%	0.0 %	0.94%
6)	Commerce	20.56%	18.91%	19.69%	21.73%
7)	Transport	4.91%	4.22%	4.11%	4.70%
8)	Finance Services	5.61%	5.13%	8.62%	7.43%
9)	Community Serivces	4.74%	1.07%	1.32%	1.38%
0)	Private Non-profit Services	0.76%	0.82%	1.0 %	1.05%
1)	Government Services	8.8 %	21.86%	16.86%	11.73%
	GDP (1)**	99.99%	99.99%	99.99%	99.98%

*GDP(t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

**Does not add to 100 due to rounding.

reasonable or practical limits. As an example, in Table 12 the share of the manufacturing sector in the total value added drops to zero when the inflation rate is minimized, rises to 4% when maximizing private consumption, and then to 6% and 11% when maximizing the increase in employment and GDP, respectively. The actual share of the industrial sector at the base year according to the plan, Table 9, is 9% and one of the targets of the plan is to raise it to 10%. The same observations can be detected in other sectors.

Although the variation is the core of the problem solution and can reflect the key sectors in the linear optimization of each objective, it would be irrational and misleading in the MODM problem since the ideal solution is the flaring light to which the whole procedure and solution is oriented.

The effects of the introduction of the sectoral constraints can be detected in the pay-off table, Table 13, where the cell values are quite rational. Table 14 shows a reasonable variation in the percentage shares of the sectors with respect to GDP.

A summary of the ideal solutions for each of the six years of the problem is depicted in Table 15, while the final solution is shown on Table 16, for the complete solution of year 1 see Appendix IV. In Table 16 the values of GDP are in real terms rather than money GDP; to obtain the money GDP the real values are to be multiplied by one plus the rate of inflation for that year $(1+\nu)$. The rate of inflation, due to money supply, ranges from roughly 2% to 17%. This seems very high for a planning exercise which is supposed to be over optimistic, but the 6-year plan itself calls for a deficit finance of about LS 285 million compared to LS 366 million in the solution. The actual government deficit for the years 1977 and 1978 is 181.3 and 131.9 million Sudanese pounds, respectively [7], while the average annual rate of inflation for the period 1970-1977 is 4% [17]. However,

Table 13. Payoff table for year 1-with sectoral constraints.*

	GDP(1)	ΔL(1)	ν(1)	C(1)
GDP(1)	1996	51	0	1412
ΔL(1)	1967	81	.1280	1412
ν(1)	1921	48	0	1519
C(1)	1957	63	.1773	1550

*GDP(t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 14. Year 1: Sectoral % shares in GDP-
with sectoral constraints.

	Sector	Objective			
		Max GDP(1)	Max ΔL(1)	Min ν(1)	Min C(1)
1)	Agriculture	35.66%	38.65%	38.16%	38.07%
2)	Mining	0.33%	0.35%	0.32%	0.33%
3)	Manufacturing	10.46%	10.00%	10.00%	10.00%
4)	Electricity & Water	1.37%	1.36%	1.88%	1.43%
5)	Building & Construction	5.14%	5.75%	4.50%	4.85%
6)	Commerce	20.15%	20.25%	21.18%	21.35%
7)	Transport	6.00%	6.00%	6.00%	6.00%
8)	Finance Services	5.78%	5.81%	6.06%	6.08%
9)	Community Services	5.27%	1.03%	1.13%	1.13%
10)	Private Non-profit Services	0.78%	0.79%	0.87%	0.87%
11)	Government Services	9.04%	10.00%	9.89%	9.86%
	GDP(1)*	99.98%	99.99%	99.99%	99.97%

*Figures do not add up to 100 due to rounding.

Table 15. Ideal values of the objective functions for each year.

Objective *	Year					
	1	2	3	4	5	6
GDP	1996	2121	2237	2377	2557	2749
ΔL	81	69	87	98	118	135
ν(%)	0	0	0	0	0	0
C	1550	1630	1722	1811	1921	2035

*GDP(t): gross domestic product for year t (LS Million)

$\Delta L(t)$: increase in employment (wages) for year t (LS Million)

$\nu(t)$: rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 16. Values of the objective functions for each year.

Objective *	Year					
	1	2	3	4	5	6
GDP	1958	2060	2185	2338	2500	2687
ΔL	62	44	60	68	72	87
$\nu(\%)$	3.6	9.5	12.8	16.9	1.7	10.8
C	1510	1600	1695	1780	1878	1991

*GDP(t): gross domestic product for year t (LS Million)

$\Delta L(t)$: increase in employment (wages) for year t (LS Million)

$\nu(t)$: rate of inflation for year t

C(t): private consumption for year t (LS Million)

these high inflation rates can be reduced in the model by either adjusting the sector's incremental capital-output ratios down or increasing the percentages of domestic savings as is exercised later. Values for GDP and consumption can best be compared by their annual growth rates as shown in Table 17, where the overall incremental capital-output ratios are also shown. The goals set by the plan for the four objectives are as shown in Table 18. The plan does not indicate the values for annual rates of inflation or deficit finance, while the increase in employment is not in terms of an increase in wages; the plan projects the values of these objectives in terms of uniform annual rates of growth.

The solution vector of the endogenous variables is shown in Table 19. The plan does not state any values for the gross output of each sector nor the other variables of Table 19 except for total imports. Other solution values for the sources of finance are also obtained as in Table 20.

Table 21 compares the values of those variables whose magnitudes are given in the plan to those given by the solution vector. In general the percentage deviation from the plan is small as can be seen in the last row, which may indicate that the model construciton, the assumptions made, and the parameters estimated, are viable. Thus the study might humbly claim that it provided a scientific approach to the problem in spite of its lack of complete data and having to rely on assumptions and borrowed or estimated data; it thus answered and filled many of the gaps pertaining to the plan and provided combined planning and implementation exercises.

1.2 The Modified Method of Satisfactory Goals (MMSG)

Another interactive method for solving MODM problems is the "Method of Satisfactory Goals" which uses the "Bounded Objective Method" interactively

Table 17. Rates of growth and incremental capital-output ratios.

	Year					
	1	2	3	4	5	6
GDP Rate of Growth*%	7.5	5.2	6	7	7	7.5
Private Consumption Rate of Growth %	6.9	6	6	5	5.5	6
Incremental Capital-Output Ratio	2.0	3.2	3.3	3.0	3.0	3.1

* Rate of growth of real income.

Table 18. Values of the objectives according to the six-year plan.

Objective*	Year					
	1	2	3	4	5	6
GDP	1959	2106	2263	2433	2616	2812
ΔL	NA	NA	NA	NA	NA	NA
ν(%)	NA	NA	NA	NA	NA	NA
C	1507	1609	1716	1829	1950	2077

NA: Not Available

*GDP(t); gross domestic product for year t (LS Million)

$\Delta L(t)$: increase in employment (wages) for year t (LS Million)

$\nu(t)$: rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 19. Solution values for other endogenous variables (in Million LS)

Variable	Year					
	1	2	3	4	5	6
X_1 (t)	936	1000	1070	1142	1223	1316
X_2 (t)	14	14	15	16	17	19
X_3 (t)	478	503	534	571	611	659
X_4 (t)	46	48	51	54	57	61
X_5 (t)	192	190	194	212	226	253
X_6 (t)	695	725	772	822	872	937
X_7 (t)	230	242	256	274	293	315
X_8 (t)	173	182	193	205	218	234
X_9 (t)	46	54	47	59	72	73
X_{10}(t)	34	36	39	40	43	45
X_{11}(t)	281	288	308	325	344	366
N (t)	264	330	419	468	490	582
S (t)	179	188	240	257	325	349
DF (t)	33	55	71	92	36	79
M_1 (t)	144	151	160	172	183	198
M_2 (t)	174	182	194	206	219	235
M_3 (t)	82	120	145	161	175	206
M (t)	400	453	499	539	577	639

Table 20. Sources of finance for the new capacity
[LS Million]

	Year						Plan Total
	1	2	3	4	5	6	
Domestic Sources [S(t) + DF(t)]	182	210	274	307	315	376	1664
1. Savings [S(t)]	149	155	203	215	279	297	1298
2. Deficit Finance [DF(t)]	33	55	71	92	36	79	366
External Sources [$M_3(t)$]	82	120	145	161	175	206	889
Total	264	330	419	468	490	582	2553

Table 21. Values of some variables given by the plan compared to those obtained by solution

Year No.	Total Imports M(t)		Gross Investment N(t) + W(t)		Private Consumption C(t)		GDP(t)	
	Value by Plan (LS Million)	% Deviation of Solution from Plan	Value by Plan (LS Million)	% Deviation of Solution from Plan	Value by Plan (LS Million)	% Deviation of Solution from Plan	Value by Plan (LS Million)	% Deviation of Solution from Plan
1	416	-3.8	358	-18.0	1507	+.2	1959	0
2	459	-1.3	401	-9.5	1609	-.5	2106	-2.2
3	503	-.8	449	+1.5	1716	-1.3	2263	-3.4
4	553	-2.5	504	+1.2	1829	-2.7	2433	-3.9
5	609	-5.2	565	-5.0	1950	-3.7	2616	-4.4
6	670	-4.6	633	0	2077	-4.1	2812	-4.4
Total	3210	-3.2	2910	-4.0	10688	-2.2	14189	-3.2

to determine a satisfactory solution; see Hwang et al [6, p.145]. In this method the DM is asked to state a set of acceptable initial goal levels which must be feasible, and then determine which one in the set of goal levels, L, is the least satisfactory (LS). This objective is then maximized subject to the original constraints formed by the remaining objective functions. Thus the problem is solved iteratively and interactively between the analyst and the DM until the best solution is obtained. The method is capable of solving both linear and nonlinear models, although the dual values from nonlinear models are hard to obtain. Another difficulty with this method is the determination of the set of initial feasible goals. In this study the problem is overcome by introducing a pay-off table like that of STEM in which the ideal solution for each objective is determined and also the values taken by the other objectives for each optimization run. This "Modified Method of Satisfactory Goals" (MMSG), besides saving the time required to determine the set of initial feasible goals, has other properties which will be explained later.

1.2.1 Details of MMSG Solution Steps

To solve by the MMSG the following steps are to be used:

Step 0. Construct a Pay-off Table and Select a Set of Acceptable Goal Levels

The construction of the Pay-off Table is exactly similar to that of STEM mentioned earlier. The DM is thus in a position where he can select his initial values of acceptable goal levels, L^1, from the pay-off table. The constraints of the problem and the set of L^1 less one (the objective to be selected as the LS in Step 1) should form a feasible region for Step 2.

Step 1. Select the least satisfactory (LS) objective:

The DM is required to identify the objective which is the least satisfactory among L^q (q is the iteration number).

Step 2. Optimize the LS objective:

In this step the LS objective is maximized subject to the constraints of the original problem and the set of L^q except the LS objective, i.e.,

$$\begin{aligned} &\text{Max. } f_{LS}(x) \\ &\text{s.t. } g_i(x) \leq 0 \qquad i = 1,2,\ldots,m \\ &\qquad f_j(x) \geq L^q{}_j \qquad j = 1,2,\ldots,k, \text{ and } j \neq LS \end{aligned} \tag{53}$$

Step 3. Decision Phase:

The analyst would first check whether f_{LS} is greater than the level set for this objective in L^q. If it is not, or if the DM is not satisifed with f_{LS}, the set of goals is revised and new goal levels are obtained, $L^{q+1} (< L^q)$, with the help of the dual variables associated with the binding $f_j(x)$'s in Step 2. The dual variables show the trade-offs between $f_{LS}(x)$ and the binding $f_j(x)$'s.

If the value of f_{LS} is higher than stated in L^q, the DM is then asked if the value obtained for $f_{LS}(x)$ can be relaxed in order to improve the other objectives. If the value of $f_{LS}(x)$ can be relaxed, proceed to the next step; if it cannot be relaxed, then the solution is the best attained level of goals.

Step 4. Selection of New Goal Level:

The DM should specify the amount of relaxation, $\Delta f_{LS}(x)$, which is acceptable, then set $q = q+1$ and return to Step 1.

For more information and simple examples for the Method of Satisfactory Goals, see Hwang and Masud [6, p. 145].

1.2.2 Solution

The same model and data for STEM are used here except that the values for the "percentage of GDP as domestic savings", $\beta(t)$, are slightly raised to reflect more optimistic domestic savings; the percentage values for each of the six years are 9.15, 10.5, 12, 13, 13, and 13, respectively.

To explain the MMSG the solution for year 1 (the model and parameter values being identical in every aspect to STEM)will be shown in the following:

Iter. #1

Step 0: Construction of Pay-off Table and Selection of the Set of Acceptable Goal Levels:

Table 22 shows the pay-off table. The DM chose the following set of acceptable goal levels:

$$L^1 = (L^1_{GDP}, L^1_{\Delta L}, L^1_{\nu}, L^1_{C})$$

$$= (1921, 51, -.10, 1490)$$

Step 1: Select the LS objective:

The DM chose f_{ν} as the least satisfactory objective.

Step 2: Optimize the LS objective:

$$\text{Min. } f_{\nu}(x)$$

$$\text{s.t. } \underline{x} \in X$$

$$f_{GDP} \geq 1921$$

$$f_{\Delta L} \geq 51$$

$$f_{C} \geq 1490$$

Table 22. Pay-off table for year 1 *

	f_{GDP}	$f_{\Delta L}$	f_{ν}	f_{C}
f_{GDP}	1996	51	0	1412
$f_{\Delta L}$	1967	81	.128	1412
f_{ν}	1921	48	0	1519
f_{C}	1957	63	.177	1550

*GDP (t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

The solution to the LP problem is

$f_{\nu} = 0.0$

$f_{GDP} = 1924$

$f_{\Delta L} = 51$

$f_{C} = 1506$

Step 3: Decision Phase:

The DM indicated that the value of f_{ν} is satisfactory and that it can be relaxed.

Step 4: Select the New Goal Level:

The DM relaxed f_{ν} i.e.

$\Delta f_{\nu} = -.0365$

and the new set of goals:

$L^2 = (1924, 51, -.0365, 1506)$

Iter. # 2

Step 1: Select the LS Objective:

The Dm selected f_{GDP} from L^2 as f_{LS}.

Step 2: Optimize the LS objective

Max f_{GDP}

s.t. $\underline{x} \varepsilon X$

$f_{\Delta L} \geq 51$

$f_{\nu} \leq .0365$

$f_{C} \geq 1506$

The solution to the problem:

$f_{GDP} = 1966$

$f_{\Delta L} = 57$

$f_{\nu} = .0365$

$f_{C} = 1506$

Step 3: Decision Phase:

The DM was satisfied with the value of f_{GDP} and it could be relaxed.

Step 4: Select the New Goal Level

The DM relaxed f_{GDP} i.e.

$\Delta f_{GDP} = -8$

and the new set of goals:

$L^3 = (1958, 57, -.0365, 1506)$

Iter. #3

Step 1:

The DM indicated that f_C from L^3 as the f_{LS}.

Step 2:

Max. f_C

s.t. $\underline{x} \in X$

$f_{GDP} \geq 1958$

$f_{\Delta L} \geq 57$

$f_{\nu} \leq .0365$

The solution to the problem:

$f_{C} = 1525$

$f_{GDP} = 1958$

$f_{\Delta L} = 57$

$f_{\nu} = .0365$

Step 3:

The DM indicated his satisfaction with f_C and his readiness to relax it.

Step 4:

The DM relaxed f_C by 15 and the new set of goals were:

$L^4 = (1958, 57, -.0365, 1510)$

Iter. #4

Step 1:

The DM selected $f_{\Delta L}$ as the f_{LS} from L^4

Step 2:

Max. $f_{\Delta L}$

s.t. $\underline{x} \in X$

$f_{GDP} \geq 1958$

$f_{\nu} \leq .0365$

$f_C \geq 1510$

and the solution to the problem:

$f_{\Delta L} = 62$

$f_{GDP} = 1958$

$f_{\nu} = .0365$

$f_C = 1510$

Step 3:

The DM was satisfied with the value of $f_{\Delta L}$ and did not want to relax it from 62. Thus the procedure was terminated and the values of the best attained goals are:

(1958, 62, -.0365, 1510)

The final compromise solution for year 1 of the plan is as shown in Table 23.

In the same manner the model was solved for the succeeding years as in Tables 24-26 inclusive. Table 27 shows the corresponding rates of growth for GDP, private consumption, and the capital-output ratios.

2. The Terminal Year Model:

The computations for equation 23, 31, 33, 39, are performed by the computer where two FORTRAN programs are written.

The terminal year model (TY) in its reduced form incorporates the private consumption variables, C(t), for the years t=1,2,...,T, in all the above mentioned equations. The C(t) variables are then replaced by their equivalent expressions as in equation (25); thus the TY model now has ρ instead of C(t) for private consumption which is in YBY model.

2.1 Solution by STEM

This model was solved by following the same steps and using the same constraints as in the YBY model. The values of the shares of the sectors in total GDP are not, however, identical to those of the YBY model which necessitated the addition of some sectoral constraints. This was adopted for two sectors only, the mining and commerce sectors where the new constraints give them a lower limit of 0.3% and 20% of total GDP, respectively. Tables 28 and 29 show the pay-off table and the problem solution, respectively. The value of the first objective, GDP(T), is for the terminal year while ΔL and ν are for the whole plan period. 'ρ' is the rate of annual growth of private consumption. It should be pointed out here that β is assumed equal to 11% of total GDP for the period.

2.2 Solution by MMSG

The same terminal year model of STEM is used here except that the value for β is assumed equal to 12% of total GDP for the period. The pay-off table and the solution for the model are shown in Tables 30 and 31.

Table 23. The final solution for year 1

Variable*	Value	Variable	Value
f_{GDP}	1958	Y_1	734.033
$f_{\Delta L}$	62	Y_2	6.551
f_{ν}	.0365	Y_3	195.800
f_C	1510	Y_4	27.690
		Y_5	97.343
X_1	936.376	Y_6	411.458
X_2	14.039	Y_7	117.480
X_3	478.466	Y_8	117.493
X_4	45.600	Y_9	37.698
X_5	192.201	Y_{10}	16.653
X_6	694.942	Y_{11}	195.800
X_7	229.888	N	360.615
X_8	173.315	DF	33.038
X_9	45.764	M_1+M_2	317.639
X_{10}	34.339	M_3	82.260
X_{11}	281.330	S	179.157

*GDP(t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 24. Ideal values of the objective functions for each year.

Objective*	1	2	3	4	5	6
GDP	1996	2130	2253	2401	2567	2762
ΔL	81	75	88	101	119	140
$\nu(\%)$	0	0	0	0	0	0
C	1550	1643	1728	1829	1931	2047

*GDP(t): gross domestic product for year t (LS Million)

$\Delta L(t)$: increase in employment (wages) for year t (LS Million)

$\nu(t)$: rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 25. Values of the objective functions for each year

Objective *	1	2	3	4	5	6
GDP	1958	2079	2207	2350	2513	2689
ΔL	62	46	60	66	74	82
ν(%)	3.6	5.0	6.0	4.0	5.0	4.0
C	1510	1602	1682	1777	1875	1992

*GDP(t): gross domestic product for year t (LS Million)

ΔL(t): increase in employment (wages) for year t (LS Million)

ν(t): rate of inflation for year t

C(t): private consumption for year t (LS Million)

Table 26. Solution values for other endogenous variables (in million LS)

Variable	Year					
	1	2	3	4	5	6
X_1 (t)	936	1001	1067	1142	1223	1315
X_2 (t)	14	14	15	16	17	19
X_3 (t)	478	508	539	574	614	657
X_4 (t)	46	48	51	54	57	61
X_5 (t)	192	185	198	210	227	245
X_6 (t)	695	728	773	821	874	934
X_7 (t)	230	244	259	276	295	316
X_8 (t)	173	183	193	205	218	233
X_9 (t)	46	71	72	74	84	84
X_{10}(t)	34	36	38	40	43	45
X_{11}(t)	281	288	306	324	344	366
N (t)	264	355	416	463	507	542
S (t)	179	218	265	305	327	350
DF(t)	33	40	47	42	50	49
M_1(t)	144	151	161	172	184	197
M_2(t)	174	183	197	206	219	234
M_3(t)	82	130	141	158	176	195
M (t)	400	464	496	536	579	626

Table 27. Rates of growth and incremental capital-output ratios.

	Year					
	1	2	3	4	5	6
GDP Rate of Growth (%)*	7.5	6.2	6.2	6.5	6.9	7.0
Private Consumption Rate of Growth (%)	6.9	6.1	5.0	5.6	5.5	6.2
Incremental Capital-Output Ratio	2.0	3.0	3.2	3.2	3.1	3.1

* Rate of growth of real income.

Table 28. Pay-off table for terminal year model*

	GDP(T)	ΔL	ν	ρ
GDP(T)	2944	378	.8706	3
ΔL	2816	536	1.1449	3
ν	2477	312	0	3
ρ	2568	367	.3056	7.9

* GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

Table 29. Solution values for the terminal year model.*

GDP(T)	2687	X_1 (T)	1296	N	2447
ΔL	393	X_2 (T)	17	S	1439
ν	.5318	X_3 (T)	657	DF	394
ρ	6.14	X_4 (T)	60		
		X_5 (T)	318	GDP	13082
		X_6 (T)	908		
		X_7 (T)	315		
		X_8 (T)	228	M_1+M_2	2355
		X_9 (T)	100	M_3	853
		X_{10} (T)	39	M	3208
		X_{11} (T)	348		

*GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

Table 30. Pay-off table for terminal year model*

	GDP(T)	ΔL	ν	ρ
GDP(T)	2944	378	.5888	3
ΔL	2816	536	.8635	3
ν	2477	321	0	3
ρ	2568	367	.0064	7.9

*GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

Table 31. Solution values for the terminal year model.*

GDP(T)	2689	X_1 (T)	1296	N	2445
ΔL	390	X_2 (T)	17	S	1570
ν	.2353	X_3 (T)	657	DF	262
ρ	6.15	X_4 (T)	60		
		X_5 (T)	306	GDP	13082
		X_6 (T)	908		
		X_7 (T)	316		
		X_8 (T)	228	M_1+M_2	2355
		X_9 (T)	109	M_3	853
		X_{10}(T)	39	M	3208
		X_{11}(T)	348		

---

*GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

3. Comparison of the Two Models by the Two Methods

3.1 The Two Models by STEM

The most suitable procedure for comparing the STEM solutions of the two models is by aggregating some of the endogenous variables and other values for the whole plan period as shown in Table 32. The results indicate how the YBY model aggregated values deviate from the TY model. However, when considering the approximations and the assumptions for the TY model, the percentage deviations of the YBY values from the TY are very reasonable and quite acceptable. The highest deviations of DF and S are due mainly to approximating the value of S as 11% of GDP in the TY model; the deviation will be reduced to 4% when DF and S are added together to represent domestic sources of finance. The next two high percentage deviations, GDP and $M_1 + M_2$, are due mainly to the approximation of the TY model by assuming equalities for the years 1 to 5. The incremental capital-output ratios, ICOR, are almost the same for the two models. The sectoral gross outputs, $X_i(6)$, for the last year of the plan, year 6, as can be noticed from Tables 19 and 29 are roughly equal.

The TY model was also tested by substituting the solution values of private consumption, C(t), for the years 1 to 5 instead of substituting the expression

$$C(t) = C(0)\ (1 + t\rho),$$

and the results are nearly identical with the model using ρ.

3.2 The Two Models by MMSG

The same comments on the comparison of Table 32 of the previous section are also valid for the comparison of Table 33 of this section. In fact Tables 32 and 33 look identical in most respects which is in effect a cross

Table 32. Comparison of aggregate values for the two models' solutions by STEM.

Aggregate for Plan Period*	YBY	TY	% Deviation of YBY from TY
GDP	13728	13082	5
ΔL	393	393	0
C	10454	10293	1.6
DF	366	394	-7
S	1538	1439	7
$M_1 + M_2$	2218	2355	-6
M_3	889	853	4
M	3107	3208	-3
N	2553	2447	4
ICOR	2.9	2.8	—

*GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

Table 33. Comparison of aggregate values for the two models' solutions by MMSG.

Aggregate for Plan Period*	YBY	TY	% Deviation of YBY from TY
GDP	13796	13082	5
ΔL	390	390	0
C	10438	10296	1.4
DF	261	262	- .4
S	1644	1570	5
$M_1 + M_2$	2219	2355	-6
M_3	882	853	3
M	3101	3208	-3
N	2547	2445	4
ICOR	2.9	2.8	—

*GDP(T): gross domestic product for the terminal year (LS Million)

ΔL: increase in employment (wages) for plan period (LS Million)

ν: rate of inflation for plan period

ρ: percentage rate of growth of private consumption

check of each model by the two methods and of the two comparisons, i.e., the percentage deviations in the two tables.

3.3 The Two Methods for the Year by Year Model.

It is highly appropriate to give some comparison of the two MODM methods, STEM and MMSG, when applied to the period by period model of this study. The two methods are evaluated on the following criteria:

1. Number of iterations
2. CPU-Time on the computer
3. Quality of results
4. Total time required for solving the problem
5. Ease of understanding
6. Information for intialization
7. Information to guide the DM

Table 34 shows the statistics for the six years for the first two criteria while Table 35 depicts the results obtained by the two methods and the ideal solution for the first year. The total time required to solve the problem, criteron number 4, is estimated as follows (excluding pay-off table as it is same):

for STEM = 2.5 hrs. X 6 = 15 hrs.

for MMSG = 1.25 hrs. X 6 = 7.5 hrs.

thus only half the time is required for the MMSG. A summary of the evaluation is found in Table 36, from which it can be concluded that the MMSG is superior to STEM in each of the mentioned criteria. For more information on comparative evaluation of MODM methods, see Hwang and Masud [6, pp. 306-309].

Table 34. CPU-time on the computer by STEM and MMSG

	STEM			MMSG		
		CPU-Time (secs)			CPU-Time (secs)	
Year	No. of Iterations	Pay-off Table	Iterations	No. of Iterations	Pay-off Table	Iterations
1	4	10.23	10.54	4	10.23	10.18
2	4	10.61	10.4	3	10.04	7.86
3	6	8.76	14.39	2	10.58	5.14
4	3	11.71	7.66	3	10.61	8.02
5	4	10.85	10.48	1	10.59	2.48
6	4	10.94	10.1	1	11.44	2.25
Total	25	63.1	63.57	14	63.49	35.93
Total CPU		126.67			99.42	
$\frac{\text{MMSG CPU}}{\text{STEM CPU}}$ 100		100 %			78 %	

Table 35. Quality of results (Numbers rounded to the nearest integer) - for year 1 +

	Method	f_{GDP}^*	$f_{\Delta L}^*$	f_{ν}^*	f_C^*
1)	Ideal Solution	1996	81	0	1550
2)	STEM	1958	62	.0365	1510
3)	MMSG	1958	62	.0365	1510

+ f_{GDP}^*: ideal value for gorwth domestic product (LS Million)

$f_{\Delta L}^*$: ideal value for increase in employment (wage) (LS Million)

$f_{\nu L}^*$: ideal value for rate of inflation

f_C^* : ideal value for private consumption (LS Million)

Table 36. Comparative evaluation of STEM and MMSG

	Criteria	STEM	MMSG
1)	Number of iterations	X	✓
2)	CPU-Time (secs)	X	✓
3)	Quality of results	✓	✓
4)	Total time for solution	X	✓
5)	Ease of understanding	X	✓
6)	Information for intialization	✓	✓
7)	Information to guide DM	✓	✓

NB: ✓ indicate superior

X indicate inferior

7. CONCLUDING REMARKS

In this chapter two multiple objective models have been developed to suit the existing six-year plan of Sudan. The objectives explicitly considered are: gross domestic product, increase in employment, inflation due to deficit finance, and private consumption. The main features of these models are as follows:

(1) They are complementary where the TY is a static MODM model to provide the scope of the plan, while YBY is a dynamic MODM model interactively tracing the development path,

(2) They combine planning and implementation with the assumption that both targets and instruments are flexible,

(3) Their construction incorporates the features of a developing economy, and a control methodology to give a meaningful programming excercise.

The models have been tested against each other to show their concurrence and complementarity by two methods for solving MODM problems. The models' results are also critically evaluated and compared with those of the actual six-year plan.

In spite of the lack of complete data and the dependence on assumptions and estimations in some situations, the models proved to be valid when being cross checked against one another and against those values given in the plan. The models not only provided most of the information incorporated in the plan, but also gave more information and thus filled some of the gaps and disaggregated some of the values in the existing six-year plan in a more scientific manner.

The manipulation of the models by sectoral constraints has contributed much to the good performance and sound results obtained in this study. The

recursive solution of the YBY model is in effect an interactive dynamic multiple objective decision making methodology with an implied feedback; this can be considered also as an attempt to make the plans of developing countries more operative.

Solving the two models by two interactive MODM methods not only provided a check on the results and a validation of the models, but also led to the modification of the existing method of satisfactory goals by removing one of its drawbacks and making it superior to the STEM method which is one of the highly recommended methods for development planning problems.

However, since these are the first MODM development planning models for Sudan, it will not be claimed that they are the best or unrevisable, especially when more accurate and complete information becomes available. It is also recommended that future studies should take into consideration the gestation lags which are natural in the development planning process.

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APPENDIX I

Terminal-year production relationship

The Leontief dynamic input-output model can be written [16, p. 84]

$$X(t) = AX(t) + Q(t) + P[X(t) - X(t-1)] \tag{1}$$

Gross Output = Intermediate Demand + Final Demands for Consumption + New Capacities Requirements

In equation (1) above it is assumed that matrices A and P remain stationary over time. Rearranging equation (1):

$$X(t) = (A + P - I)^{-1} [PX(t-1) - Q(t)]. \tag{2}$$

If we let $H = (A + P - I)$, and provided H^{-1} exists then equation (2) becomes:

$$X(t) = H^{-1} PX(t-1) - H^{-1} Q(t) \tag{3}$$

By induction on the system of nT equations, equations (3), may be reduced to n restrictions:

$$X(T) = (H^{-1}P)^{T}X(0) - \sum_{t=1}^{T} (H^{-1}P)^{T-t} H^{-1} Q(t). \tag{4}$$

Multiplying both sides by H equation (4) becomes

$$HX(T) = (PH^{-1})^{T-1} PX(0) - \sum_{t=1}^{T} (PH^{-1})^{T-t} Q(t). \tag{5}$$

Rearranging equation (5) and substituting for the final demand

$$HX(T) + \sum_{t=1}^{T} (PH^{-1})^{T-t} [w W(t) + cC(t) + gG(t) + eE(t)] \leq (PH^{-1})^{T-1} PX(0) \tag{6}$$

APPENDIX II

Linearizing the private consumption constraint

Equation(24) of Chapter V is:

$$C(t) \geq C(0)\ [1 + \rho]^t \tag{1}$$

for t = 1.

$$C(1) \geq C(0)\ [1 + \rho] \tag{2}$$

for t = 2.

$$C(2) \geq C(0)\ [1 + \rho]^2 \tag{3}$$

$$C(3) \geq C(0)\ [1 + \rho]^3 \tag{4}$$

etc.

The series $[1 + \rho]^t$ can be expanded as follows:

$$[1 + \rho]^t = 1 + t\rho + \frac{t(t-1)}{21}\rho^2 + \frac{t(t-1)(t-2)}{31}\rho^3 + \ldots.$$

for $(-1 < \rho < 1)$

by neglecting the second order terms

$$[1 + \rho]^t \simeq (1 + t\rho)$$

Equation(1) is thus approximated by

$$C(t) \geq C(0)\ [1 + t\rho]$$

APPENDIX III

Total GDP and imports during the plan period

The Leontief dynamic input-output model can be written as:

$$X(t) = AX(t) + Q(t) + Z(t) \tag{1}$$

Gross Output = Intermediate Demand + Final Demands for Consumption + New Capacities Requirement

For a finite planning horizon T, the summation of the two sides of equation (1) gives:

$$\sum_{t=1}^{T} X(t) = A \sum_{t=1}^{T} X(t) + \sum_{t=1}^{T} Q(t) + \sum_{t=1}^{T} Z(t) \tag{2}$$

It should be noted that the last term in equation (2) is:

$$\sum_{t=1}^{T} Z(t) = \sum_{t=1}^{T} P[X(t) - X(t-1)] = P[X(T) - X(0)]$$

By rearranging equation (2) becomes:

$$[A - I] \sum_{t=1}^{T} X(t) = P[X(0) - X(T)] - \sum_{t=1}^{T} Q(t) \tag{3}$$

or

$$[A - I] \sum_{t=1}^{T-1} X(t) + [A - I]X(T) = PX(0) - PX(T) - \sum_{t=1}^{T} Q(t)$$

$$[A - I] \sum_{t=1}^{T-1} X(t) + [A + P - I] X(T) = PX(0) - \sum_{t=1}^{T} Q(t)$$

$$\sum_{t=1}^{T-1} X(t) = [A-I]^{-1}[PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] \tag{4}$$

where $H = [A + P - I]$

The final demand vector Q(t) can be split into two vectors, one for the exogenous values, Q*(t), and one for endogenous value of private consumption, C(t)c. Thus:

$$\sum_{t=1}^{T} Q(t) = \sum_{t=1}^{T} [Q^*(t) + C(t)c] \tag{5}$$

and

$$\sum_{t=1}^{T} C(t)c = [\sum_{t=1}^{T} C(t)]c \tag{6}$$

Total GDP for the plan period is found by adding X(T) to both sides of equation 4 and multiplying by $i'(I - A' - \hat{m}_3)$ i.e. $GDP = i'(I - A - \hat{m}_3) \sum_{t=1}^{T} X(t)$

$$= i'[I - A' - \hat{m}_3) \{(A-I)^{-1} [PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\} \tag{7}$$

In the same manner intermediate and consumer goods imports for the whole plan period is

$$M_1 + M_2 = (m_1 + m_2)' \sum_{t=1}^{T} X(t)$$

$$= (m_1 + m_2)' \{(A-I)^{-1} [PX(0) - \sum_{t=1}^{T} Q(t) - HX(T)] + X(T)\} \tag{8}$$

APPENDIX IV

The STEM solution for year 1.

Step 0. Construction of pay-off table

The ideal solution, f_j^*, for each of the objectives, f_j, is found by solving n LP problems:

$$\max \text{ (min)} \quad f_j(\underline{x}) = c_j^T x$$

$$\text{s.t.} \quad Ax \leq b, \; x \geq 0$$

$$j=1,2,\ldots,n$$

For each of the n optimization problems (n=4 in this study) the values of the other three objectives are also computed. The pay-off table for year 1 is:

	f_{GDP}	$f_{\Delta L}$	f_ν	f_C
f_{GDP}	1996	51	0	1412
$f_{\Delta L}$	1967	81	.128	1412
f_ν	1921	48	0	1519
f_C	1957	63	.177	1550

Iteration No. 1:

Step 1. Calculation phase

a) Calculation of weights

$$\alpha_{GDP} = \frac{f^*_{GDP} - f^{min}_{GDP}}{f^*_{GDP}} \left[\frac{1}{\sqrt{\sum_{i=1}^{k} (c_i^{GDP})^2}} \right]$$

$$= \frac{1996-1921}{1996} \left[\frac{1}{2.0235} \right]$$

$$= .0186$$

$$\alpha_{\Delta L} = \frac{f^{*}_{\Delta L} - f^{min}_{\Delta L}}{f^{*}_{\Delta L}} \left[\frac{1}{\sqrt{\sum_{i=1}^{k} (c_i^{\Delta L})^2}} \right]$$

$$= \frac{81 - 48}{81} \left[\frac{1}{1.1567} \right]$$

$$= .3522$$

$$\alpha_{\nu} = \frac{f^{min}_{\nu} - f^{*}_{\nu}}{f^{min}_{\nu}} \left[\frac{1}{\sqrt{\sum_{i=1}^{k} (c_i^{\nu})^2}} \right]$$

$$= \frac{.177 - 0}{.177} \left[\frac{1}{1} \right]$$

$$= 1.0$$

$$\alpha_{c} = \frac{f^{*}_{c} - f^{min}_{c}}{f^{*}_{c}} \left[\frac{1}{\sqrt{\sum_{i=1}^{k} (c_i^{c})^2}} \right]$$

$$= \frac{1550 - 1412}{1550} \left[\frac{1}{1} \right]$$

$$= .0890$$

$$\pi_{GDP} = \frac{\alpha_{GDP}}{\alpha_{GDP} + \alpha_{\Delta L} + \alpha_{\nu} + \alpha_{c}}$$

$$= \frac{.0186}{0.186 + .3522 + 1 + .0890}$$

$$= \frac{.0186}{1.4598}$$

$$= .0127$$

$$\pi_{\Delta L} = \frac{.3522}{1.4598}$$

$$= .2413$$

$$\pi_{\nu} = \frac{1}{1.4598}$$

$$= .6850$$

$$\pi_{c} = \frac{.0890}{1.4598}$$

$$= .0610$$

b) Solve the LP problem

$$\begin{aligned} &\min_{(\underline{x},\lambda)} \quad \lambda \\ &\text{s.t.} \quad \lambda \geq [f^*_{GDP} - f_{GDP}(\underline{x})]\,\pi_{GDP} \\ &\qquad \lambda \geq [f^*_{\Delta L} - f_{\Delta L}(\underline{x})]\,\pi_{\Delta L} \\ &\qquad \lambda \geq [f^*_{\nu} - f_{\nu}(\underline{x})]\,\pi_{\nu} \\ &\qquad \lambda \geq [f^*_{c} - f_{c}(\underline{x})]\,\pi_{c} \\ &\qquad \underline{x} \in X \\ &\qquad \lambda \geq 0 \end{aligned} \Bigg\} = X^1$$

The solution to this problem is:

$$\underline{f}^1 = (1961,\ 70,\ .1773,\ 1507)$$

Step 2. Decision phase

The DM indicates that $f^1_{\Delta L}$ is satisfactory and can be relaxed, i.e.,

$$\Delta f_{\Delta L} = 8$$

The feasible region is now to be modified for the next iteration cycle, i.e.,

$$X^2 = \begin{cases} x^1 \\ f_{GDP} \geq 1961 \\ f_{\Delta L} \geq 70 - 8 = 62 \\ f_{\nu} \leq .1773 \\ f_c \geq 1507 \end{cases}$$

Iteration No. 2:

Step 1. Calculation phase

a) Calculate weights

$$\pi_{GDP} = \frac{.0186}{.0186 + 1 + .0890}$$

$$= .0168$$

$$\pi_{\Delta L} = 0.0$$

$$\pi_{\nu} = .9029$$

$$\pi_c = .0803$$

b) Solve the LP problem

$$\min_{(\underline{x},\lambda)} \quad \lambda$$

$$\text{s.t.} \quad \underline{x} \in X^2$$

$$\lambda \geq 0$$

The solution to this problem is:

$$\underline{f}^2 = (1961, 62, .1767, 1538)$$

Step 2. Decision phase

The DM finds that f_c^2 is satisfactory and can be relaxed, i.e.,

$$\Delta f_c = 28$$

The feasible region for the third iteration cycle is thus:

$$X^3 = \begin{cases} x^1 \\ f_{GDP} \geq 1961 \\ f_{\Delta L} \geq 62 \\ f_\nu \leq .1767 \\ f_c \geq 1538 - 28 = 1510 \end{cases}$$

Iteration No. 3:

Step 1. Calculation phase

a) Calculate weights

$$\pi_{GDP} = .0182$$

$$\pi_{\Delta L} = 0.0$$

$$\pi_\nu = .9818$$

$$\pi_c = 0.0$$

b) Solve the LP problem

$$\min_{(\underline{x},\lambda)} \lambda$$

$$\text{s.t.} \quad \underline{x} \in X^3$$

$$\lambda \geq 0$$

The solution to this problem is:

$$\underline{f}^3 = (1968, 62, .148, 1510)$$

Step 2. Decision phase

The DM indicates that f^3_{GDP} is satisfactory and can be relaxed, i.e.,

$$\Delta f_{GDP} = 10$$

The feasible region for the fourth iteration cycle is:

$$X^4 = \begin{cases} x^1 \\ f_{GDP} \geq 1968 - 10 = 1958 \\ f_{\Delta L} \geq 62 \\ f_{\nu} \leq .148 \\ f_{c} \geq 1510 \end{cases}$$

Iteration No. 4:

Step 1. Calculation phase

a) Calculate weights

$$\pi_{GDP} = 0$$
$$\pi_{\Delta L} = 0$$
$$\pi_{\nu} = 1.0$$
$$\pi_{c} = 0$$

b) Solve the LP problem:

$$\min_{(\underline{x},\lambda)} \quad \lambda$$
$$\text{s.t.} \quad \underline{x} \in X^4$$
$$\lambda \geq 0$$

The solution to this problem is:

$$\underline{f}^4 = (1958, 62, .0365, 1510)$$

Step 2. Decision phase

The DM indicates that all the objectives of $\underline{f}^4$ are satisfactory, thus $\underline{f}^4$ is the final solution (the compromise solution $\underline{x}^4$ is shown in Table 17).

CHAPTER VI

SUMMARY AND CONCLUDING REMARKS

The major objective of this study was to demonstrate that the overall economic development planning process in Sudan can be greatly improved, even in the absence of complete data about the economy and its structure, by following a few simple scientific techniques. For this end the study managed to:

(1) model the economy by input-output methods,

(2) relate planning to implementation in Sudan,

(3) use multiple objective decision making (MODM) models and methods suitable for Sudan and other developing countries.

In Chapter II, the basic theory of input-output models is presented. The overview is to provide the readers of a developing country with a simplified concept of input-output tables: how they are prepared and maintained, their practical applications, and how they are related to the system of national accounting. It also explains the different planning models in use and how to choose a model for a developing country. In addition a quick survey of the experience of some developing countries with input-output tables and the arguments for and against input-output models for developing countries is presented.

The development plans of Sudan through a quarter of a century are presented and compared in Chapter III. From available literature and the experience of the author in the formulation of the manufacturing sector's plan and its coordination during the five-year plan of Sudan, and also his participation in the preparation and steering of the first "Engineers' National Conference" where development and the "Interim Action Programme" are part of the theme, the three development plans of Sudan are exposed with respect to their formulation and implementation. A diagnostic approach is adopted in order to find the common problems for the three plans with respect to formulation and operation.

In Chapter IV a new input-output model is developed: first a survey of the existing models of Sudan is conducted, the RAS method of updating input-output tables is explained in detail with its algorithm presented in a form suitable for computation, finally the methodology followed in developing the new input-output table is stated in a step by step form. The data used to obtain the results in this chapter is from real data of Sudan.

Two MODM models for Sudan are developed in Chapter V. The first is a year by year model (YBY), and the second is a terminal year model (TY). The models are solved by using real data of the six-year plan of Sudan and parameters computed from the developed input-output table of Chapter IV. Two MODM methods are used to solve the two models, STEM and the "Modified Method of Satisfactory Goals" (MMSG). The MMSG is a method developed in this study from the existing "Method of Satisfactory Goals" for solving MODM problems. Comparisons of the results of the two models and the two methods are finally performed. The solution to the planning problem of Sudan indicated that the models not only simulate the plan well but also give more information than provided by the actual six-year plan. The modified method of satisfactory goals (MMSG) not only succeeded in resolving the difficulty of the original method it also proved to be superior to the STEM method in this application.

The possibilities of future study to extend the work reported in this study are discussed next:

On Improving the Input-Output Table and the Methodology:

In spite of the success of the procedure and methodology used to develop a new input-output table for Sudan from an obsolete table more improvements are still required. The input-output table can be improved greatly if the data is provided in the form compatible with the entries of the input-output table, and if more external or exogenous information about some sectors are

available. Concerning the methodology used, also a great improvement will be achieved if all historical data of national income accounting is utilized for validating and adjusting the input-output table from the simulation results of the table. This form of adapting the coefficients of an obsolete input-output table by some accumulated historic data of national income accounts can also be used to adapt input-output tables imported from countries of similar economic structure, that is, in other words, the construction of input-output tables by an adaptive I/O method.

Improving the MODM Models of Sudan:

The two models perform very well when the plan is in the form presented in the six-year plan of Sudan, however, more improvement is expected to take place in the planning process and consequently the models may require some improvements. Instead of the simple assumption of instantaneous investment, lagged investments may deem more appropriate. The capability of the economy to service debts and principal payments may be necessary to incorporate into the model. Imports of consumer goods, after proper classification, are better treated as controllable rather than endogenously determined. Another important extension necessary for the models of Sudan and other developing countries is the incorporation of non-economic or non-quantifiable factors which usually prevail in developing countries and obstruct the plan implementation and operation. The optimization or MODM solutions can thus be tested for sensitivity not only with respect to changes in parameter values but also to these and other random factors. This could be in a form of a system dynamics MODM model.

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MULTI-SECTORAL AND MULTIPLE OBJECTIVE MODELS FOR ECONOMIC DEVELOPMENT PLANNING—CASE OF SUDAN

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Economic development plans of Sudan and other developing countries have been a source of disappointment to their people by failing to improve their standard of living. From the short experience of the author in the planning field and the available literature it seems that the Sudan suffers, beside other things, from the ineffectiveness of the planning process, and a defective framework of planning. Thus the objective of this study is to demonstrate that the planning process of Sudan can greatly be improved, even in the absence of complete data, by following a few simple scientific techniques. This is approached by: modeling the economy, combining planning and implementation, and finally the use of multiple objective decision making (MODM) models and methods.

In the absence of formal economic models, especially multi-sector input-output tables which have the characteristic that they can be transformed easily into consistent mathematical models, the usual procedure is to borrow other countries' models. Instead of importing an input-output table the study will develop a heuristic methodology to obtain an updated input-output table from an obsolete one and from the annual national income accounting data for Sudan. The same methodology can be extended to borrowed input-output tables. The methodology consists of reconstruction, updating, validating, adjusting, and an exogenous modification of the technical coefficients of the table.

An overall economice development planning problem should include, for practical purposes, both planning and implementation in one model. Plans in Sudan and other developing countries are usually considered as blueprints instead of regarding them as working plans to be reviewed constantly and revised periodically. These problems of planning, implementation, and flexibility can be handled by intrinsically incorporating them in the modeling methodology and construction. In this study, in addition to incorporating the planning and

implementation problems, the overall plan is rendered operational by using two models. The first is a terminal year (TY) model which gives the scope and terminal conditions for the overall plan; the second is a year by year (YBY) model which traces the path followed to reach the terminal conditions.

Preferred solution planning is more compatible with the overall planning problem than is optimization planning, because the problem is usually characterized by a multiplicity of conflicting objectives. In this study multiple objective decision making (MODM) techniques are used to solve the two models (TY and YBY) whose construction is in fact coupled to this technique.

The simulation of the models and methods is carried out by a set of real data of Sudan (the six-year plan, 1977/78-1982/83, data). Two MODM methods are used, the STEP-method (STEM) and a modified (modified by this study) method of satisfactory goals (MMSG). A comparison of STEM and MMSG is also made. The YBY model is solved recursively for the six years of the plan. It is in effect an attempt to introduce a dynamic interactive multiple objective decision making methodology (DMODM) with an implied feedback.

In addition to simulating the planning and implementation process the study also provides a capsule of the input-output method and its related aspect for a developing country, a description of the updating technique known as the RAS method together with a detailed algorithm and a documented computer program in FORTRAN, and also a critical review of the development plans so far made for Sudan.

While some improvements and refinements may be needed to make the three models (the input-output model, the terminal year model, and the year by year model) for Sudan a reliable planning tool, the models proved to be valid and meaningful and can greatly help the planners and researchers in Sudan.