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This report reviews several analytical models which can be used for estimating the regional economic development impacts of water resource projects. A review of the history of Corps of Engineers efforts to introduce a working concept of economic development in various regions of the United States is also included. The final section of the report presents the theory, techniques and data sources for three analytical models and evaluates each model.

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REGIONAL DEVELOPMENT IMPACTS AND THEIR MEASUREMENTS

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CHAPTER I

INTRODUCTION

Federal Water Resource investments serve both national and regional interests. Efficiency criteria has been advocated and used as the sole means of evaluating these projects. Efficiency criteria is defined as the addition of goods and services to the national economy or the improvement of productivity due to the project as compared to not doing the project. The need for a project or the initiation of one often originates from the region itself and this regional interest claims to serve both long and short run national interests. Using efficiency or the sole criteria, however, has often been criticized for its insufficiency in estimating that a regional project indeed also serves the national interest.

This criticism has brought about concern for a host of issues in the process of project evaluation such as the need of estimating regional development benefits (RDBs), environment quality, the well-being of people, etc.

A. The purpose of this report is twofold:

1. to trace the brief history of issues, statutory development and Corps efforts surrounding regional development benefits in the process of water resource project evaluation;
2. to introduce three alternative quantitative methodologies which have recently been developed by the IWR in estimating RDBs resulting from navigation projects for the benefit of Corps staff. These are:

   a) The multiregional variable Input-Output Model (MRVIO):

   b) The Multiregional Multi-Industry Model (MRMI); and

   c) The Linear Programming/Economic Base Evaluation Model (LPEB).

B. The outline to be followed in this report will be: a brief history of issues, statutory developments of RDBs and Corps efforts (Chapter II); a presentation of the theory, techniques, data requirements and sources and evaluation of the MRVIO, MRMI, and LPEB in that sequence (Chapters III, IV, and V).

CHAPTER II

REGIONAL DEVELOPMENT BENEFITS (RDBs): ISSUES AND CORPS EFFORTS

A. EVALUATION CRITERIA FOR RDBs

The Benefit-cost evaluation of federally funded water resource investment projects goes back to the often quoted 1936 Flood Control Act, which provided the first written guidance for the executive branch. The Act quthorized federal participation in flood control schemes "if the benefits to whomsoever they may accrue are in excess of the estimated cost." Due to this act, the practices of measurement of benefits and costs for the evaluation of projects was spread among agencies with various searching efforts in theory and practical methodologies.

1. Green Book and BOB Circular No. A-47

In order to provide a more systematic and consistent basis for the analysis of water resource projects among various agencies it was found necessary to develop a theoretically sound basic framework of benefit-cost analysis. The Subcommittee Report to the Inter-Agency on Water Resources in 1959 became the first document which codified some principles, standards, and procedures for the economic evaluation for water and related land projects. This is often called the "Green Book" (Inter-Agency, 1958). The first administrative guidance for the B/C analysis, Bureau of Budget Circular No. A-47, 1952, was extensively drawn from this report. The Subcommittee Report was further revised in 1959.

Although the Green Book and Circular No. A-47 have been improved by the addition of several new guidelines, their overall content still represents the basic approach to B/C analysis. The basic contents of B/C analysis as illustrated in the Green Book may be summarized as follows:

a) The basic objective of the economic analysis in the planning of water resource development programs is to provide a guide for the efficient use of the required economic resources in producing goods and services in order to satisfy human wants;

b) Although a comprehensive public viewpoint is stressed, the project evaluation is limited to economic considerations with efficiency criteria. Efficiency criteria is defined as the objective of public spending to maximize the value of output or national income for the resources used.

c) The measurement of diverse effects resulting from a given project including measuring tangibles as well as intangibles is stressed. Market-derived values (monetary basis) will be applied whenever possible, for the common unit of measurement and supplemented by quantitative and qualitative statements for intangibles.

d) To avoid over estimation of project impact the benefits from the project are measured by the difference of expectations with and without the project, because an automatic economic growth is expected even without the project conditions.

e) The Committee report chiefly relied on primary benefits. Secondary benefits from alternative projects may offset each other; therefore the net secondary benefits of a project would be negligible on the selection of the project. Primary benefits are attributable to the use of primary output of the project, while secondary benefits stem or are induced from the primary benefit. For example: the primary benefit of an irrigation project is the increase of national income due to the increase in agricultural product resulting from the project. The increased income resulting from milling of increased agricultural product is a stemming benefit; income benefit induced by the consumption expenditures of farmer's earning due to the irrigation project is an induced benefit.

f) The value of project outputs is measured on the willingness-to-pay basis, inputs are valued by foregone opportunity costs.

g) The rate of yield of long-term Federal bonds will be used as the discount rate. The rate is assumed free from risk and uncertainties associated with the project;

h) To aid in decision making, the excess of benefits to costs (net benefits) and B/C ratio are calculated. The selection criteria is a project which exhibits the maximum net benefit.

i) The selection of a particular project design requires that it be the most economical among the alternative means.

j) Principles and typical standards in measuring benefits and costs associated with different project types are briefly introduced in the Green Book, but the detailed implementation is left open to project planners.

2. Senate Document No. 97 (U.S. Senate, 1962)

The Senate Document No. 97 which broadened objectives, essentially resulted from adverse Congressional reaction to the narrowly defined economic efficiency, emmphasis of the BOB's Circular No. A-47. The Senate Document has opened the door for a more comprehensive approach toward an objective B/C analysis by including national, state, local viewpoints as well as those of different economic groups. The examination of the economic effects of a project included:

a) Tangibles and intangibles;

b) Primary and Secondary; and

c) Short and long-term consequences on the economy. These points are summarized in the following excerpts from the Senate Document:

The following emphases were placed on the process of a plan formulation (Senate Document 97., pp. 2-8).

> All viewpoints - national, regional, State, and local shall be fully considered and taken into account in planning resource use and development . . . Comprehensive plan and project formulation shall be based upon an analysis of the relationship of goods and services to be provided by a proposed resource use or development to available projections of national, regional, state, and local requirements and objectives . . .A comprehensive public

viewpoint shall be applied in the evaluation of project effects. Such a viewpoint includes consideration of all effects, beneficial and adverse, short range and long range, tangible and intangible that may be expected to accrue to all persons and groups within the zone of influence of the proposed resource use or development . . . When secondary benefits are included in formulation and evaluation of a project proposal, planning reports shall indicate (a) the amount of secondary benefits considered attributable to the project from a national viewpoint. Such benefits, combined with primary benefits, shall be included in the computation of a benefit/cost ratio; (b) secondary benefits attributable to the project from a regional, state, or local viewpoint. Such benefits shall also be evaluated, when this procedure is considered pertinent, and an additional benefit/cost ratio computed . . .Presentation in planning report shall include an explanation of the nature of each type of secondary benefit taken into account from either viewpoint and methods used in the computation of each of their values.

This document opened the way to the evaluation of multi-objective planning of a multipurpose project. The diverse impacts resulting from a multiobjective project may bring conflict among each objective and requires trade-offs.

3. The Appalachian Regional Development Act

The Appalachian Regional Development Act of 1965 (Public Law 89.4) directed the Secretary of the Army to ". . .prepare a comprehensive plan for the development and efficient utilization of the water-related resources of the Appalachian region, giving special attention to the need for an increase in the production of economic goods and services within the region as a means of expanding economic opportunities." The Act further stated that ". . .regional development is feasible, desirable, and urgently needed." Thus, the major intent of the Act was directed toward assistance in resolving the region's special problems, promoting economic development and meeting common needs on a coordinated and concerted regional basis. The Coosa River Navigation Project was a response to this act. It explicitly evaluated potential regional development benefits attributable to this project.

4. Blue Book (Water Resource Council, 1970)

To implement the Senate Document No. 97 a special task force was created in 1968. The product of the task force became the Blue Book: Procedures for Evaluation of Water and Related Land Resources Projects: Findings and Recommendations of the

Special Task Force of the U.S. Water Resources Council. The multiobjective planning concept was endorsed by the Congress through Section 209 of the River and Harbors Act of 1970.

The Blue Book established a detailed working procedure in B/C analysis by broadening planning objectives. The objectives cited were divided into four categories: (a) national economic development (efficiency objective); (b) environmental quality; (c) social well-being (equity objective); and (d) regional development. The project plan became, basically, a multiobjective planning approach. A social accounting system is used to show how favorable and unfavorable impacts will be distributed under differing objectives and alternative means available. Economic principles and identification of benefits and costs relevant to different types of project purpose are expanded.

Secondary benefits and costs are replaced by external economies and diseconomies. The possible, favorable and unfavorable impacts due to externalities are measured and are included in national development benefits.

5. Most Current Federal Register: Principles and Standards for Planning Water and Related Land Resources

The initial version of the Blue Book has gone through several changes. Consequently the social well-being and regional development objectives are omitted from the formal objective function of a B/C analysis in the most recent Federal Register (Water Resource Council, 1982). However, the regional benefit issue has not disappeared. The register allows the description and measurement of regional development impact if the impact is significant for the project evaluation. The inclusion of the regional impact depends on the Army Secretary's discretion. Issues which are closely related to national versus regional benefits are real versus pecuniary and primary versus secondary benefits (costs) problems.

a) Real versus pecuniary

Since real benefits are those derived from final consumption, they, by necessity, represent an increase in the community's welfare position.

Such benefits are then constrasted against the real costs incurred when reallocating resources to the public sector. Pecuniary benefits and costs, on the other hand, result in a shift of benefits (costs) among groups in the society. Since the gains incurred by some individuals are offset by losses to others there is no gain/loss to the society as a whole. Instead, the latter merely represents an economic transfer.

b) Primary versus secondary

The terms "direct" and "indirect" are often used interchangeably for the terms of "primary" and "secondary". Primary benefits are sometimes applied to user benefits, whereby benefits accrue directly to the users of the main product of a project. On the other hand, secondary benefits are associated with spillover or side effects which accrue to non-primary product users or to non-primary objective functions.

Let us assume that a federally financed hydropower project is planned for an area which is characterized by high unemployment and idle resource capacity. The single objective of the project is to supply low-cost electric power to the community where demand is very high. A substantial amount of the community income and employment will be increased as a result of the project implementation. A careful evaluation shows that the increase of income and employment is a result of: (i) the increase in income from power sales; (ii) low cost electric power making manufacturing production more profitable; (iii) increased return to scale to those firms which operate at less than optimum level before the project's introduction; and (iv) an income multiplier effect due to project expenditures. The project evaluation will also reveal that income will be redistributed favorable from the outside regions to the lower income class in the project region.

According to the classification of primary and secondary benefits in the previous discussion the first category belongs to primary benefits of this project while the rest are secondary benefits. It is often argued whether secondary benefits should be counted in national income benefits. This depends upon the planner's point of view. If he takes a national viewpoint, then, any benefits (costs) which are of a pecuniary nature should not be included. In the above, the income multiplier effect is offset by a decrease in supplies elsewhere due to an increase of taxes. Therefore, this constitutes pecuniary benefits. However lower production costs and increased returns to scale are considered to be real productivity gains to the society and thus can be counted as national income benefits. If there are idle resources the benefits resulting from the use of otherwise idle resources are claimed as genuine secondary benefits and are credited to national income benefits. Externalities, such as lower production cost and increased return to scale, and distributional impact are very difficult to measure. Moreover, such external economies are often counteracted by cost elements.

Because of the difficulty in measuring and in order to guard against an exaggerated claim of pecuniary types of secondary benefits, regional development benefits are not encouraged, because they are considered mere transfers. The implication of treating the regional development benefits as mere transfer is the full employment assumption with constant return to the scale. This is not reality. Most project investments are of regional origin. One can see the issue becomes a continuing one.

B. CORPS EFFORTS IN MEASURING REGIONAL DEVELOPMENT IMPACTS

The Army Corps of Engineers, as a member of the Water Resource Council, has been continuously searching for better guidance in formulating policy, standards and procedures for the evaluation of water resource project investments. The Corps has been developing several quantitative models for the measurements of regional development impacts resulting from the navigation project through the IWR. The first attempt of a quantitative impact evaluation model was the measurement of short-run construction impact of the McClellan-Kerr Arkansas River Multiple Purpose Project (Kim, 1977). This model was an interregional I/O model which utilized Polenske's data from MRMO (Polenske, 1970). The model's products were output, employment and income and their multifliers by 83 industry sectors and four regions resulting from construction expenditures for the Arkansas River Investment Profect. The model was characterized by fixed regional, technical coefficients and trade coefficients.

Very recently, IWR has developed four alternative quantative models for the evaluation of regional development impact resulting from a navigation project. The impacts range from a long-run transportation cost saving effect to short-run effects such as construction, recreation, power generation impacts. For comparative purposes, the Coosa River Water Project has been evaluated by each model. Those models are:

1. The multiregional variable Input-Output Model (MRVIO) (Liew and Liew, 1980, 1981 and 1982);

2. The multiregional multi-industry model of the U.S. Economy (MRMI) (Urban Systems, 1982);

3. Linear Programming/Economic Base Model (LPBE) (Lowis and Terrance, 1982);

4. Industrial Location Model Analysis (ILMA) (Plantec, 1982).

The brief analysis of the first three models will be presented in the following chapters. The ILMA Model is not presented because the model is

very similar to the LPBE. The main difference is that ILMA uses a location analysis in estimating the changes of industrial output for the sectors which are directly affected by the low cost water transportation in the impact region. This modeling system requires input and output tonnages for each industrial activity and their origins and destinations and fits well with standard procedures used by the Corps of Engineers to identify potential commodity flows associated with navigation projects. The primary analytical procedure is to calculate the differential growth in transportation as a result of the Project and to convert it into changes in output, income, and employment. ILMA measures the indirect impact through the RIMs multipliers. RIMs multipliers are regional I/O multipliers which will be otained through BEA, Department of Commerce.

CHAPTER III

THE MULTIREGIONAL VARIABLE INPUT-OUTPUT MODEL (MRVIO)

The Multiregional Variable Input-Output Model (MRVIO) was designed by Professor Liew of the University of Oklahoma, (Liew and Liew, 1981 and 1982) for the evaluation of the low cost navigation impact of the McClellan-Kerr Arkansas River Multiple Purpose Project. This model has also been used for the evaluation of the Coosa River Project. The navigation impact is a long-run impact of a water resource investment. The IWR previously studied a short-run construction impact of the same project using the Multiregional and Multi-industry Input-Output Model (MRMO), (Kim, 1979).

The MRVIO Model is a multiregional and multi-industry input-output model with variable technical and trade coefficients. By using varying technical and trade coefficients the model tries to evaluate the income as well as the substitution effect of a navigation project due to changes in input costs and output prices. The model aims primarily at measuring a long-run transportation cost saving impact but can be extended to measure other impacts such as increased construction and recreation spendings and changes in revenue of electric power generation and transportation costs resulting from the project investment.

Some weaknesses of a conventional multiregional and multi-industry I/O model in the evaluation of economic changes have been:

a) The regional input-output coefficients are fixed regardless of changes in output prices, input costs, tax structure, or shipping costs. The conventional input-output models thus fail to respond to either substitution or the output-mix behavior of industries when these costs or prices change.

b) Neither input cost nor output price would affect an industry's decision on output and input mix, employment, income, and trade structure.

c) The trade coefficients remain fixed regardless of a change in shipping cost or purchase price of inputs in the region.

A navigation project creates not only income effects but also substitution effects resulting from changes in cost and price structures through lowering shipping costs.

The theoretical rigor and sophistication of the MRVIO model is described in the Arkansas Water Study {Liew-Liew, (1981)}. The MRVIO Model is consistent with theory of well-behaved firms. The basic hypothesis of the model is that firms are sensitive to the changes in input costs, tax structures, and output prices. Changes in input or output prices will alter input-output mixes in order to minimize cost and maximize profit. A change in input composition and output distribution, therefore, will alter regional, technical, and trade coefficients, location of production, employment, income and choice of shipment mode. Under the MRVIO model, the regional input-output and trade coefficients become endogenous to the model. The model measures the developmental potential of the regional and national economies in terms of industrial outputs, employment, income, trade structure, equilibrium price level, and interindustrial structure.

A. DERIVATION OF EQUILIBRIUM PRICES AND STRUCTURAL COEFFICIENTS

The model is derived from the dual relationship between the production frontier and the price frontier. Profit-maximizing conditions permit the derivation of an additive and homogeneous price frontier for each product. The price frontiers were explained by input elasticity, transportation cost, wage rate, service price of capital, tax rate and technical progress parameters. The input elasticity measures the percentage change in the quantity of output in response to one percent change in input price. The technical progress parameter is the state of technology in a production function. Both input elasticity

and technical progress parameters were estimated by the Coefficients of a linear logarithmic Cobb Douglas production function. The elasticity becomes the value share of each input after tax.

The simultaneous solution of all these price frontiers yields the profit-maximizing price level (equilibrium price level). The equilibrium price determined then enters the input-output transformation function as an explanatory variable. Therefore, wage rate, capital cost, land price, transportation cost and tax rate affect the equilibrium price which, in turn, determines the technical and trade coefficients. For the mathematical derivation of MRVIO see Appendix I, The Theoretical Exposition of the MRVIO.

B. OUTPUT OF THE MODEL AND BALANCE EQUATION

Industrial output, income, and employment in each region identify the industrial location, land use patterns, and regional growth. The trade flow identifies the physical distribution of commodities and the regional market structures. The model answers many policy-sensitive questions. It measures the impact of the waterway on regional development and predicts industrial location, interregional trade flow, interindustry purchases, and market structure of industrial sales. The specific types of impact measurement covered are:

1. A transportation cost saving impact;
2. A construction spending impact;
3. A recreational spending impact;
4. A residential water supply impact;
5. An electric power impact;
6. A flood control impact.

These measurements are estimated through the exogeneous changes in the

final demand vectors which represent the initial shock of regional economic activities due to the project. The ultimate impact of the shock will be measured by solving the balance equation of the interregional I/O model. The impact measurement is not recursive but takes a static approach. The target year in which the most impact falls was designated.

The balance equation is expressed by the following matrix:

$$X = (I-TA)^{-1}Ty = (I-TA)^{-1}F$$

where:

X, Y, F are industrial output and final demand received and final demand shipped and has the relationship of Ty = F.

I, T, A are matrices of identity, regional trade coefficients and technical coefficients respectively.

$(I-TA)^{-1}$ is the Leontief inverse matrix.

From the balance equation a change of industrial output (Δx) can be expressed as a change of TA $\Delta(TA)$ and a change of the final demand (ΔF) and decomposed into the substitution and income effects:

$$\Delta x = (I-TA)^{-1} \ '\Delta(TA)x) + (I-TA)^{-1}\Delta F$$

$$= \underline{\text{the substitution effect}} + \underline{\text{the income effect}}$$

The substitution effect captures the change in industrial output due to changes in costs and the income effect describes the change in industrial output due to a change in spending.

C. REGIONAL AND INDUSTRIAL CLASSIFICATION

In order to benefit from utilizing data, economic as well as social, and geographical space, which must be adequate to accomodate the project impact, individual counties are used as the building blocks for regional classification. For the purpose of the Arkansas Water project study the United States economy was divided into the following three regions:

1. Region I (The Primary Impact Region) which consists of 28 adjoining

counties to the waterways from the state of Arkansas and Oklahama, 5 counties in the state of Arkansas, and 13 counties from Oklahoma.

2. Region II, which consists of the states of Arkansas and Oklahoma, excluding waterway counties, which are included in Region I.

3. Region III, which consists of the remainder of the United States.

The user may choose an alternative method of classification if another geographical division better suits the needs of the study.

For a regional study, a two-digit industrial classification system is employed since the available supporting data are consistent with the two-digit Standard Industrial Code (SIC) classification system. The categorization of industries is made so that a single industry would not produce more than 15% of the economy's total out put and the region's most important industry should be an industrial classification system. The 35 industrial sector classification is used for each region based on both SIC and Bureau of Economic Analysis Codes. The 35 industry sectors included seven agricultural sectors, seventeen manufacturing sectors, three mining sectors, seven service and related industries sectors, and one government sector. For the Coosa River study the model adapted four regions and 31 industry sector classification.

D. DATA REQUIREMENTS AND SOURCES

The model consists of three data sets: some exogeneous and estimated through production function and some are endogeneous which include model output.

1. Exogeneous variables:

   Regional industrial output and prices and value added, including wage rate, service prices of capital, tax rates for the model building; Transportation cost and final demand.

2. Input parameters:

   Input elasticities and technical progress parameters.

3. Endogeneous variables:

Equilibrium industrial prices,

Regional technical and trade coefficients, Interindustry and Interregional transactions, Industrial output, income, employment and multipliers.

a. Estimation of Reginal Output and Value Added

Since there is no quality data for the output and value added and its components (wage rates, service price of capital and tax rates) the national control total must be allocated to State and County level. National output, intermediate input, value added (Wages, non-wage income, tax payment) for each industry were estimated from the BEA input-output file. 1972 was selected as the base year since the most current national input-output table was developed for that year and the national table provides the basis for the derivation of all regional input-output tables used in this study.

To arrive at Regional variables, those County variables were aggregated to make proper Regional variables. To allocate the national variables to State and County level, the following proxy variables were used.

The Variables Employed to Allocate the National Total to Regional Level

	State Level		County Level	
	Value Added	Output	Value Added	Output
Agriculture	Cash Receipt by Agricultural Commodity	Market Value of Agricultural Product Sold	Production	Production
Mining	Census Value Added	Value of Production	Value of Production	Value of Producion
Manufacturing	Value Added reported by the Annual Survey of Manufacturer	Value of shipments reported by the Annual Survey	Taxable Payrolls	Taxable Payrolls
Other Sectors	Estimated Value Added by Kendrick Jaycox Method	Value added by Kendrick-Jaycox Method	Taxable Payrolls	Taxable Payrolls

b. Estimating Industrial Prices, Wage Rates and Service Prices of Capital

The industrial prices, wage rates and the service prices of capital for the period of 1968 to 1978 must be estimated since these price data are required to evaluate the economic impact of the Arkansas Navigation System on the waterway counties, the rest of Waterway System and the rest of U.S.

The industrial prices and the wage rates for the period of 1967 to 1978 were gathered first and indexed based on 1972=100.

The price indices of the industrial goods were gathered primarily from the Handbook of the Labor Statistics. These data were supplemented by information contained in Oklahoma Agricultural Statistics, and Oklahoma Energy Assessment and Forecasting. Employment and Earnings which is published by the Bureau of Labor Statistics is the main source for nonagricultural wage data while farm wage rates were gathered from Agricultural Statistics.

The service price of capital is not usually available and thus it was estimated based on the wage and the price series by using the Divisia Index Method:

$$\log (r/r_{-1}) = \frac{1}{S_K} \{(\log P/P_{-1}) - s \log (w/w_{-1})\}$$

Where:

log - the natural logarithm.

P: - Price index of industrial output.

w: - Wage index of wage rates.

r: - The service price index of capital (the service of capital includes land, machines and plants).

S_L - The value added share of the wage payment.

S_K - The value added share of the non-wage payment (since indirect taxes are excluded from the value added, ($\{s_L + s_K\}$ becomes a unity).

c. Estimating Regional Final Demand

State final demand pattern which was estimated by Jack Faucett Associates Scheppack (1972) has been prorated to the County level and these County final demands were summed for each Region to arrive at the Regional final demands. The variables used for prorating State final demand to the County level were:

Final Demand Component	Prorated Variables
Consumption	County personal income
Government spending	Local Government expenditures
Investment and others	County industrial output

d. Estimation of Regional Technical Coefficients

In estimating regional technical coefficients a non-survey method was used.

Regional technical coefficients were estimated from the 1972 U.S. input-output tape (496-industrial classifications) by using a product mix method. This method assumes that the different degrees of industrial mix in each region cause the regional coefficients to vary from one region to another.

National I/O table is aggregated to 35 industry sectors in each region by deleting the column industries which are not found in the particular region based on the information from the County Business Pattern. The regional technical coefficient a_{ij}^r (ith input purchase by industry j in region r) is estimated by

$$a_{ij}^r = S_{ij}^r \, (x_j^r - v_j^r) \, x_j^r$$

Where:

S_{ij}^r = the intermediate purchase share of the ith input by industry j in region r;

v_j^r = value added by industry j in region r;

x_j^r = industrial output by industry j in region r.

For the Coosa River study National I/O Table is estimated from the INFORUM, Interindustry Forecast of the U.S. Economy at the University of Maryland.

e. Estimating Trade Coefficients

The percentage of a commodity received from other regions is called the trade coefficient. Estimating trade coefficients requires a complete set of interregional trade flows. The Census of Transportation, Carload Way Bill Statistics, Waterborne Commerce of the U.S., the Census of Mineral Industries and the Census of Manufacturers were the sources from which the basic data needed to estimate trade flows were obtained. The 1963 trade flow estimate amoung States is available from MRMO.

The 1963 trade flows aggregated from 79 commodities to 35 commodities from Oklahoma, Arkansas and the rest of the U.S. using the output shares between the waterway region and the non-waterway regions as the allocating variables. Both Oklahoma and Arkansas trade flows were further disaggregated into the waterway, the nonwaterway regions of Oklahoma and Arkansas. Next, the trade flows of the water way counties were obtained by combining those of Oklahoma and Arkansas. The trade flows of the non-waterway regions of Oklahoma were compiled in a similar fashion. Thus, three 35 commodity trade coefficients were obtained for the three regions. The 1972 trade coefficients were then automatically updated for the target year (1974-1978) by the RAS method. The same method has been applied for the Coosa River study except four region 31 industry sector classification.

E. DATA LOCATION IN THE DISK FILE

The Data collected and estimated are stored on Disks as described in the User's Manual. If the user desires to permanently alter any of the basic data, it can be done by reading the data set name and by replacing it with a new data set.

Unlike the basic input data, the user supplied input is the data which is most likely to be continuously modified by the user. The user supplied input

is stored as a categorized data set so that the user can list and make changes whenever such changes are desired. Examples of user supplied inputs are the transportation cost savings data and the final demand matrix.

F. OPERATING THE SOFTWARE PACKAGE

The MRVIO software package is a fully interactive system. When the program is logged on via a terminal, it displays instructions and question on the typewriter-like terminal or video screen and waits until the user responds to the question which, at this point, is all that is required of the user. If the user accidentally enters a wrong message, he can prevent the execution called by the erroneous message by striking a "break" or "interrupt" key.

The MRVIO software package consists of a main program (ARKAN.FORT) and several supporting subprograms. Some subprograms are in the program library entitled (D.LIEW.PROGRAM1). The ARKAN.FORT utilizes several data sets which are stored in the disk file. These data sets include 'D.PART.DATA5' contains all the necessary basic input data. The remaining three data sets are all categorized and can be edited from the Time Sharing Operator (TSO) terminal. The user may choose any one of the six menu numbers to perform the study. For example if the user should type 1 to perform the transportation cost saving study, type 2 to perform the construction spending impact study, and so on. Once the study number is selected further instructions will be displayed on the terminal.

When the user has responded all questions posed by the program on the terminal, the MRVIO package executes the program and prints the computer output the terminal facility. The computer output includes the changes in industrial output, value added, personal income and employment for each industry

in each region for the target years, (1974-1979). If desired, the user can instruct the computer to print the industrial output both with the project in being and without the project, as well as the changes which occur in total industrial output, and the percentage changes which occur in the industrial output of each industry in each region.

G. EVALUATION OF THE MRVIO

The strength of this model lies in three basic characteristics: 1) it generates a vast amount of information, particulary interindustry and interregional structural information, and multipliers; 2) it provides varying structural coefficients enabling the model to estimate optimal behavior of a firm, including choice of location in the production and marketing process; 3) it operates economically in terms of computer time if economic activities resulting from the project are transformed into regional final demand vectors. A weakness inherent in the model, as in any interregional I/O model, arises from the inability of the structures of the technical coefficients and the trade coefficients to reflect changes over a long period of time e.g., the trade coefficients used in this study is based on 1963 transportation and census data. The assumption of perfectly elastic supply must also be considered as a weakness when using this I/O model.

CHAPTER IV

MULTIREGIONAL MULTI-INDUSTRY MODEL

(MRMI)

This model was developed by Professor Curtis Harris at the University of Maryland (Harris, 1972, 1973, 1974, and 1980) and used by Urban Systems & Engineering Inc. (Urban System 1982) in the evaluation of RDB's for the Coosa River Project. The model has been successfully utilized (1) to compare program alternatives to complete the United States Interstate Highway System, (2) to evaluate a segment of the Interstate Highway System, and (3) to evaluate the impact of port deepening options. The MRMI model is a large scale econometric model based on a large number of industry sectors and founded on county level data.

There are two operating versions of the model. One version considers the county as the basic geographic unit of analysis. The other considers the U.S. in terms of 585 regions consisting of 266 Standard Metropolitan Statistical Areas (SMSAs) and 183 non-SMSA portions of Bureau of Economic Analysis (BEA) areas. It is, therefore, unusually flexible in determining impacts by small regions and detailed industry sector and is a national model. The MRMI operates in a recursive mode using estimates for time "t" to generate estimates for time "t + n," to generate overall national estimates which are consistent with independent forecasts such as the INFORUM model at the University of Maryland (Almon 1974) and OBERS projections from Bureau of Economic Analysis, Department of Commerce.

Nine national macroeconomic variables which constrain national economic and population growth will be forecasted outside INFORUM model. INFORUM model which is a black box to MRMI is a national input-output model. INFORUM is designed for long-term projection of the level of output, employment and income

for over 200 industrial sectors, given the economic and demographic constraints. It is a dynamic and recursive model. The input-out coefficients are allowed to change, based on their long-term trends and the projection for the t + 1 year is based on the final demand vector which is the product of the t year projection.

MRMI is a national projection model and at the same time it is a regional projection model. A regional projection, based on the changes in the level of economic forecasting variables in the forecasting equation, shows the change in the regional economic activities. The regional changes, however, result only from shifting the relative regional shares within the projected national changes. The sum of regional changes become the national change which is a fixed set of projected values, regardless of the change in particular regional economic conditions unless the regional economic change leads to a change in the national constraints for the INFORUM model.

Unlike the MVRIO model, this model is neither an interregional nor a national I/O model. However, the model starts with the national control total variables in output, employment and income for the industry sectors which are the products of the I/O model. MRMI including INFORUM consists of four principal components:

a) Projection of national constraining variables for the INFORUM model;

b) the INFORUM for the projection of national industry control total variables;

c) Four sets of functional equations which represent MRMI include:

   i) a set of location equations to project changes in regional output;

   ii) a set of demographic equations to estimate key demographic variables;

   iii) the transportation linear programming model for the estimation of a shadow price of transportation;

vi) final demands equations

d) a set of output variables and programming aids for the impact analysis.

The regional development impacts are measured by the differences in regional economic activities between without project conditions (base line projection) and with project conditions. The projected economic growth pattern of a region without the project condition is set by the location equation of the region based on the regional shares of national economic and demographic control variables. Projected changes in the regional economic development pattern with the project are estimated by alternating the regional shares of independent variables of the location equation due to the project. The level of independent variables of a location equation due to the project is derived by adding the direct impact of the investment project, in terms of spending or level of costs, to the particular impacted-region over the years by industrial sector due to the project investment. Growth patterns of both with and without project conditions are time series data. The changes in the level of economic variables in a location equation in the impacted region, however, are designed to offset the non impaced region (the rest of the U.S.) so that the sum of regional changes must equal the projected national control totals.

The MRMI produces a vast amount of data including output, employment, income, capital investment, intermediate purchases, private and public consumption expenditures, final demand and exports and imports by industry and region. The model also provides various demographic variables of each region. The vast amount of variables, and the statistics involved with this model, require summary forms for the impact analysis. Programming aids assist in this regard.

The model consists of 104 industrial sectors, 73 equipment purchasing sectors, 26 construction sectors, and 24 general government sectors. The regional classification for this model is:

a) Region I - The 10-county Coosa River Corridor between Montgomery and Gadsden, Alabama.

b) Region II - The 8-county Gulf Coast Region including Jackson County, Mississippi; Baldwin and Mobile Counties, Alabama; and Escambia, Santa Rosa, Okaloosa, Walton, and Bay Counties, Florida.

c) Region III - The 55 remaining counties in Alabama.

d) Region IV - The rest of the United States

A. THEORETICAL BASE OF MRMI

The theoretical basis for MRMI is embodied in the principles of location theory. The question addressed in the regional model is: Where will the required national output be located? Central to the theory is the concept of location rent. In its simplest form location rent is a measure of economic advantage and is directly related to the costs of shipping a producer's goods to the marketplace. The notion of profits exists through the interaction of a demand curve for a good and the location of producers. That is, producers will enter the market until a supply-demand equilibrium exists. The equations that are used to estimate regional economic activity in the U.S. reflect the processes by which major production and household location decisions are made.

As the location decisions of industries depend on regional differences in production costs, the regional patterns of investment depend on the production decisions. Therefore, in the MRMI model, regional investment demand is related to the changes in regional production. The location of jobs by place of work is also related to production. The location decisions of individuals are similar to that of firms. Individuals migrate to regions if the regions have low unemployment rates, high wages, and good employment opportunities. Thus, the MRMI equations that forecast population are formulated to include changes in employment by place of residence, and relative unemployment in the region. The estimates of regional final

demand are derived endogenously, reflecting demand both by consumers and industries. In other words, regional demand is induced by changes in regional production patterns and not vice-versa as in input-output models.

The equations that are used to estimate regional economic activity in the U.S. reflect the processes by which major production and household location decisions are made. In MRMI, structure is imposed by representing locational change as a recursive dynamic process. The series of "snapshots" are fixed intervals of time -- each a single year -- where at the beginning of the period there is a set of profits which vary by location to which industries adjust by relocating. The relocations, however, cause changes in projits which are recognized at the beginning of the next period causing another round of relocations, and so on. Although the internal detail of MRMI is in four separate sets of equations, the model operates in a single framework with many interdependencies and linkages among its various components.

1. Industry location equations

The principal driving force in the model is a set of industry location equations that explain changes in output by region using independent variables that represent components of profits. The explanatory variables include location rent, the value of land, prior investments in equipment, prior production, and agglomeration variables which are identified as population density, the economic size of major buyers, and the economic size of major suppliers. The agglomeration variables represent external effects on the industry. In addition to transportation and other costs, the proximity of buyers or suppliers and population density are used as independent variables in location equations. The location rent associated with an industry embodies marginal costs of shipping products, marginal transportation costs of obtaining inputs, and labor costs.

Total demand and supply variables proxy for individual buyers and suppliers of an industry's products.

The coefficients of the equations in the model are estimated by ordinary least squares procedures, using pooled cross-section and time-series data for the years 1970-74. The parameters are estimated using each county (or region) as an observation; that is, there is a separate equation for each industry but the same coefficients are used for a given industry in all regions. The regional differences are expressed by the different intercepts for each industry equation by region. All dependent variables in the model's equations are expressed in terms of regional shares of national totals rather than regional levels of output, employment, etc.

2. Labor Force and Demographics Equations

Once the location of output is determined and the changes in production are estimated, employment by place of work and by place of residence, labor force, and population are derived in the demographic equations of the MRMI model. Changes in the location of production influence the decisions of individuals to migrate and locate in the region. Demographic equations consist of functional equations which are estimated by the following functional relationships:

a) Jobs by place of employment by industry is a function of the level of industrial output and capital investment adjusted by net commuter and multijob holding patterns;

b) Population migration by age and race is a function of regional wage rates, changes in regional employment and relative unemployment of a region over the nation;

c) Regional population is a function of prior population, natural growth rate and migration;

d) Regional payrolls by industry is a function of employment and capital investment.

e) Regional personal income is a function of payrolls and other components of income.

3. Transportation Shadow Price and Interregional Dependencies

The input costs having the most regional variation are transportation costs of shipping both the outputs and the inputs. The procedure used for estimating the marginal transportation costs is to compute shadow prices from a linear programming transportation problem. The transportation submodel in MRMI is a classical transportation problem where the total cost of transporting a commodity between producing regions and market regions is minimized. In this way, the competitive economic structure among regions is recognized. The LP submodel requires a set of inputs which include transportation rates for shipping each commodity between any pair of producing and market regions. It also requires total interregional exports and imports of each commodity. The exports constrain the total shipments out of a region while imports limit the shipments into a region. The estimate of the shadow transportation prices (marginal TC) for ith industrial good between region j and k is to estimate x's by minimizing the equation

$$\sum_{j=1}^{M} \sum_{k=1}^{M} {}_i f_{jk} \, {}_i x_{jk} \qquad (i = 1,\ldots,N)$$

subject to

$$\sum_{k=1} {}_i x_{jk} \leq {}_i S_j$$

$$\sum_{i=1}^{M} {}_i x_{jk} = {}_i D_k$$

$$_i x_{jk} \geq 0.$$

where:

$_iS_j$ = supply of output for industry i produced at region j measured in dollars.

$_iD_k$ = requirements (demand) of industry i's output located at region k measured in dollars.

$_if_{jk}$ = the transportation cost of shipping a dollar's worth of industry i's commodities produced in region j to region k

$_ix_{jk}$ = the flow of goods produced by industry i from region j to region k.

i = 1,..., N where N is the number of industries.

j,k = 1,..., M where M is the number of regions.

There are two sets of shadow prices:

$_is_j$ = the cost of shipping a marginal dollar's worth of goods produced by industry i from region j.

$_ir_k$ the cost of receiving a marginal dollar's worth of goods produced by industry i into region k.

The shadow prices are used as independent variables in the location equation. The primary purpose of solving the transportation problem for the over-all model is to obtain the shadow prices but the outputs of the submodel also include optimum shipments of commodities among regions (regional demand and supply).

4. Final Demand

Total regional demand by industry consists of the following major groups:

- intermediate demand by other industries;
- personal consumption expenditures;
- equipment purchases;
- construction expenditures;
- government expenditures; and
- foreign exports.

Personal consumption expenditures by industry sector and region are formulated

to depend on regional personal income. Regional equipment expenditures by industry, and construction are formulated to depend on changes in output and the level of output by industry. Residential and related private construction expenditures, and public construction expenditures are related to regional personal income, while other private construction expenditures are related to output. Government expenditures and exports are derived using either prior estimates of these variables or personal income. Finally, the intermediate demand estimates are derived by applying technical input-output coefficients to the estimates of regional output. The regional final demand vector is endogenous to the model.

B. INPUT REQUIREMENTS AND SOURCES

1. INFORUM requirements for macroeconomic guidelines

The macroeconomic forecast required for INFORUM is not a true macroeconomic forecast in itself as this national inter-industry model contains an endogenous macroeconomic component. Rather, the exogenous forecast consists of a set of projections of key parameters which are subsequently used to constrain the INFORUM macro to prescribed growth rates. The set of variables projected exogenously in the evaluation of the Coosa River Navigation Project consisted of the following:

- population
- households
- percentage of households with age of head 25-34
- government spending (both federal and state and local)
- per capita disposal income
- labor force
- military employment
- civilian employment (total, farm, non-farm, government)

Though few variables are exogenously specified and most of these variables are published in government and private sector forecasts. Very long-term forecasts of several of the macroeconomic variables required for INFORUM are, however, published by the Bureau of Economic Analysis, U.S. Department of Commerce (OBER Data). Other variables not available from this source must be extracted from other forecasts or projected independently using simple estimated relationships between the desired variables and long-term data series that are available.

2. National Control Total Variables for the Regional Projection

National control variables are derived in a two-stage process whereby first, a macroeconomic forecast is developed and then a national inter-industry forecast is made. As an existing national input-output model INFORUM is used for this purpose. In order to have comparability with data definition in MRMI output, personal consumption expenditures, defense and other variables, 200-sector detail at the national level from INFORUM is aggregated to 104-sector detail for MRMI. Equipment and employment estimates must be expanded to 73 and 108 sectors, respectively. All dollar values are converted from 1977 to 1976 dollars.

3. Other data requirements and sources

Variables required for location and demographic equations other than INFORUM data for the county level must be collected. The titles of those data and their sources are shown below:

Variables Required for MRMI and Sources

Variables	Sources	Variables	Sources
Population	Bureau of Economics Analysis, Bureau of the Census	Employment	Bureau of the Census and Bureau of Economic Analysis
Births and Deaths	HEW, Public Health	Payrolls	Bureau of the Census and Bureau of Economic Analysis
Unemployment	Bureau of Labor Statistics	Agriculture Output	Bureau of Economic Analysis
Commuters	BEA	Mining Output	Bureau of the Census and Department of Interior, Bureau of Mines
Personal Consumption Expenditures	Bureau of the Census	Manufacturing Output	Bureau of the Census
Federal Government Expenditures	National Archives	Fishery Output	Department of Commerce
State and Local Government Expenditures	Bureau of the Census	Utilities Output	Department of Energy and Bureau of the Census
Private Construction Expenditure	Bureau of the Census	Retail Trade Output	Bureau of the Census
Public Construction Expenditure	Bureau of the Census	Exports and Imports	Bureau of the Census

4. Direct Impact Data

In order to measure the impact of the project the user of the model must supply Direct Impact Data resulting from the investment. The indirect and induced impact of the project will be estimated by the MRMI model. The direct impact data is an initial shock of change in regional economic activity due to such factors as increase in construction expenditures resulting from the project investment. These data must be identified by the industry sector, region and year of occurence.

i) Construction, Operation and Maintenance Impact Data:

Direct impacts should be expressed in terms of construction and equipment expenditures. Construction expenditures, as defined in the model, account for all expenditures <u>except</u> equipment purchases. The pattern of construction and equipment expenditures may be estimated either through the General Design Memorundom (GDM) or using the pattern of expenditures associated with the recognized 26 different categories of water system construction. For O&M impact the expenditures for labor will be allocated the federal government; equipment expenditures are allocates to the corresponding industry sectors.

ii) Transportation cost saving and Transportation Revenue Impact Data:

These data are estimated from the traffic survey of potential users by the Army Corps of Engineers. The tonnages which were estimated to be shipped by mode and destination before and after project comple tion up to 2039 were multiplied by shipping rate for both pre-project and post-project to obtain revenue differences for each carrier.

iii) Power Generation and Revenue Impact Data:

It is assumed that all water used for lockage is lost for power generation for the percentage of time flows are at or below turbine capacity and the calculation of average annual power loss at each lock was based on data provided by GDM. Gross revenues correspond to output in Sector 70, "Electric Utilities"; therefore, a reduction in revenues represents a reduction in regional outputs in that sector. The revenue losses for each county were then totalled and subtracted from the base-line output in sector 70.

C. OUTPUT FROM THE MODEL AND PROGRAMMING AIDS

Output generated by the model is a series of cross-sectional data bases, each containing measures of economic and demographic activity for all regions explicitly recognized by the model for a single year. Because of its recursive nature, the model must produce a complete data file every year of the forecast to generate input data for the next forecast year. But as soon as their functions are performed, the files are scratched to minimize storage requirements.

Because of the sheer size of the data base, several programming aids have been developed to facilitate the analysis of forecasts. The programming aids are designed to retrieve and display forecasts of selected economic and demographic indicators by industry, region, and year and regional aggregate. The model forecasts variables in terms of the level and rates of growth over time period for both baseline projection and impacted projection. The programming aids also enable the printout of the summary indicators for the benefit of comparative study.

D. OPERATION OF THE MRMI MODEL

The operational procedures of MRMI are summarized in the following steps:

1. Macro economic data to constrain INFORUM is projected and passed to INFORUM consulting group at the University of Maryland; INFORUM producer national inter-industry forecast of 200 sectors output and employment.
2. This data is adjusted to 1976 dollar base and aggregated to 104 industrial sectors and 73 equipment purchasing sector and 26 construction sectors to fit the MRMI model.

3. All counties or economic areas are identified according to the defined impact regions and the rest of the nation so that all regional economies can be separately identified.

4. Generate a baseline regional forecast. All relevant information concerning the scenario is contained in a "set-up" file which informs the program about the beginning and end years of the forecast, the number of regions to be processed, the forecast files (years) to be retained (all others are scratched), and the names of input and output files that have to be attached for the model to run.

5. Develop direct impact data and allocate the data to the county or economic areas that make up the impact regions.

6. Generate an impact forecast. Run procedures for generating an impact forcast are nearly identical to those of the baseline forecast. Input files are identical (unless a second national control file has been developed for the impact scenario) and output files are renamed to permit the distinction of scenarios for later comparative analyses.

7. Analyze the model's output. Because MRMI forecasts so much data, regional forecasts are not directly interpretable from unprocessed output files. The Programming Aide file is used to print out the summry data for the impact analysis.

8. Since this model assumes that any regional investment must be offset by another region. The regional output projection with impact scenario will be a mix of positive and negative regional gains. Any increase in regional gain due to the project must be at the expense of other regions. This implies that any regional gain is the result of a transfer. Compared to other models, MRMI tabulates the positive gains of regional development benefits and negative gains which consist of transfers.

E. EVALUATION OF MRMI

MRMI is one of the most extensively documented multiregional models in existence. The county or standard metropolitan statistical area (SMSA) can be the smallest region with detailed disaggregated industry sectors. Unlike an interregional I/O model projection of this model is consistent with the availability of national resources. Economic variables, demographic variables and transportation shadow prices are allowed to interact to determine the location rent, the level of output, employment and income. MRMI is a comprehensive and flexible model. The model produces time series data of economic and demographic statistics from national to county level based on alternative national growth scenarios.

Some of the weakenesses of MRMI are as follows:

1. Although the model is based on a multiregional and multiindustry frame work the model does not provide the structural information such as interindustry and interregional slow of goods and services, nor feedback effects.

2. The location equation which is the key behavioral equation in determining output, employment and income of a region is applied across the nation except for transportation shadow price which is the product of a linear program algorithm and the key regional variable to distinguish a location rent. Other coefficients of the location equation are fixed. The independent variables in location equation are limited numbers which satisfy the regression equation which are based on a mix of cross section and time series of county data from 1974-1977. The equation is less stable in reflecting regional production function.

3. The model is fairly easy to construct but the model contains times series county economic and demographic data. This requires a great cost in maintaining a big memory space and uses long computing times and print outs.

4. To follow the Water Resource Project Evaluation Guideline the model assumes full employment in the impact region. Any increase in regional gain is assumed, therefore a mere transfer from other regions. For this purpose the the direct impact to the region is subtracted from the rest of-nation. The basic assumption of full employment of the impact region is not a reality or the direct impact necessarly offset from the rest-of-nation. The productivity of regions may not be the same even if one assumes full employment.

CHAPTER V

LINEAR PROGRAMMING/ECONOMIC BASE EVALUATION MODEL (LPEB)

This model was designed by Drs. Glover and Lewis (Glover & Lewis, 1983) for the evaluation of the regional development impact of the proposed Coosa River Waterway Project. The model was initially developed for the study of Rde River Waterway Project. (Lewis et. al., 1980) the basic theoretical concept of this model is based on the "location theory" and optimizing behavior of firms to capture the competitive advantage generated by lower input costs resulting from the navigation project. The new transport cost conditions, especially water transport cost, alter the profitability of water-oriented industries defined as basic industry in the impact regions, and thus alter the output levels of those industries. The increase of output of water-oriented industries stimulate the output of suppliers to the basic industries. The additional capacity for transporting inputs into various regions to produce industry output can also serve to alter output levels produced. The increase of output leads to the increase in employment and earnings which necessarily increase the output of service and government sectors and population of the region.

The linear programming model (Direct Evaluation Module) is used to estimate the level of outputs of industries which are benefited directly by the low water transportation costs. The increase of employment and income of the water-oriented industries due to the project and the indirect and induced impact (output, employment and income) of the water-oriented industry on the other industries and service and government sectors are estimated by the economic base evaluation model (Secondary Effect Module). The LPEB consists of two main estimation modules: (1) Direct evaluation module which is a linear programming submodel, and (2) secondary effect module which is an economic base model.

Primarily, the linear programming procedure is used to derive the changes in output of industries which directly benefited from implementation of a specific water development project. The economic base procedure is used to transform these output changes into output changes in those industries which are linked to those directly impacted. The economic base model also is used to derive direct and indirect employment, population, and earnings changes resulting from the original direct output changes. This model is primarily designed for measuring the transportation cost saving impact resulting from the project but could be extended to evaluate the construction impact and to measure transportation cost savings.

Alternative transport costs and barge traffic capacity are of particular importance in carrying out an evaluation of a proposed waterway. A "with" and "without" analysis of impacts can be carried out using the model outlined by simply imposing a constraint system that is representative of existing production and transport conditions to simulate the "without" project profit. Then a new mode and its associated transport cost and traffic capacity is introduced, and the "with" project conditions are generated by a new solution to the model. Profit, output, impact commodity flow, and secondary impact conditions of the "without" or "existing" case can be compared with the "with" project case.

The industries whose cost and transport structures are represented in the linear programming system are water project, or specifically water-transport-oriented. These are termed the basic industries or sectors. There are other basic sectors representative of a significant part of any regional economic base, which are not sensitive to changes in the water input or water transportation. The output from these latter sectors is used as input in the basic and water-oriented sectors and are, therefore, indirectly affected by the water-

oriented sectors. Their cost structure is not represented in the linear programming system, but the linkage between output changes in the water-oriented sectors and output changes in these industries is specified in the economic base system. Similarly, output change linkages are represented for the nonbasic sectors which include trade, finance, service, and government sectors.

The model uses 20 sector industrial classification and two impact Regions: Coosa River Waterway Region and Gulf Cost Region. The rest of the U.S. was used as a third region but the impact on the third region was not measured.

A. DIRECT EVALUATION MODULE-LINEAR PROGRAMMING MODEL (LP)

The industry sectors which are subject to the LP model are water oriented industries. These industries are directly benefited from the low cost water transportation for their inputs required and their output for the market. To estimate output of basic industries the commodity flows among regions and possible cost structure among alternative modes are required.

Waterway traffic flow projections have been developed by the U.S. Army Corps of Engineers (1981), and include tonnage of various products which potentially could be transported on the proposed waterway and the associated transport costs for barge transport and alternative transport modes. It was necessary to aggregate various specific commodities from the flow projections into sectors associated with the Standard Industrial Classification of industries. Sector to sector flow patterns (seven water-oriented sectors) were developed for each region including the two direct impact regions. A summary of the flow Projections by sector for the initial year of the proposed waterway operation (1990) and for 2040 were estimated. Given the above information the LP model is used in estimating the level of output with new transportation cost constraints.

The LP model is to

MAXIMIZE (NET PRICE X INDUSTRY OUTPUT - TRANSPORT COSTS)

SUBJECT TO:

THE FOLLOWING CONSTRAINTS

PRODUCTION PROCESS CONSTRAINTS

MODE CAPACITY CONSTRAINTS

INPUT AVAILABILITY CONSTRAINTS

DEMAND CONSTRAINTS

SUPPLY CONSTRAINTS.

The net price used is gross industry output price net of per unit labor and capital costs. Total intermediate input costs could not be subtracted since only the costs of those inputs which potentially could flow on the waterway and then be converted to output in the "basic" sectors effected by the waterway could be accounted for in developing the model input data base. The input availability constraints account for the amount of product (as input) for each sector that is available to be converted to output in any sector in each producing region. Input availability for any producing region is the sum of the amount of product or input which could be transported to that region by the waterway and amounts which could be transported by other modes, and all of which is converted into various industry output levels. Since all of the input availbility constraints over all regions sum up to the supply constraint for this particular problem, the supply constraint is actually nonoperative in the model. This is the meaning of perfectly elastic supply as in a non constrained I/O model.

The model can now be expressed mathematically as:

$$\text{Max} \sum_{m}\sum_{k}\sum_{l}\sum_{j}\sum_{i} (P_{jl}Q_{jl} - T_{iklm}x_{iklm}) \tag{1}$$

subject to:

Production process constraints

$$\sum_{j} b_{jl}Q_{jl} - \sum_{i} a_{ijl}x_{ijl} = 0 \tag{2}$$

Mode capacity constraints (3)

$$\sum_{i}\sum_{k}\sum_{l} x_{iklm} \leq C_{im}$$

Input availability constraints (4)

$$\sum_{j} x_{ijl} \leq \bar{x}_{il}$$

Demand constraints (5)

$$\sum_{k} x_{ikl} \geq \tilde{x}_{il}$$

Supply constraints (6)

$$\sum_{l} x_{ikl} \leq \bar{x}_{ik}.$$

Where:

P_{jl} = the net price of jth output in producing region l.

Q_{jl} = the maximum production of output j in producing region l.

T_{iklm} = the per unit transport cost of shipping input i from region k to region l by mode m.

x_{iklm} = the level of shipment of input (or product) i from region k to region l by mode m which can be converted to industry output.

b_{jl}, a_{ijl} = the production coefficients, where b_{jl} is a transformation between outputs, and a_{ijl} is the input per unit of output conversion coefficient.

x_{ijl} = the amount of input (or product) i used to produce industry output j in producing region l.

$\bar{x}_{il}$ = the available quantity of input (or product) i in producing region l.

$\bar{x}_{ik}$ = the maximum supply of input (or product) i in input supplying region k.

$\tilde{x}_{il}$ = the minimum demand of input (or product) i required to be met in producing region l.

C_{im} = The total transport capacity of transport mode m in terms of units of input (or product) i.

Optimization of the model is carried out first under existing production and transport conditions "without" the availability of the Coosa River Waterway. Then optimization is carried out with new transport costs associated with the introduction of the waterway to obtain new output levels which result under new profitability conditions. The output changes are then used as input data in the secondary impacts model. The output changes of the "with waterway" model solution relative to the "without waterway" solution are expressed in terms of percentage change.

Sensitivity analysis can be performed using the modeling system to assess the impacts of alternative projections of constraint values on optimal output, input use, and product flow levels. For example, alternative input availabilities, production capacities, or transport mode capacities could be imposed on the model and new optimal solution for these new constraint levels could be derived. Similarly, price and/or transport cost changes could be imposed and a new solution could be obtained.

B. THE SECONDARY EFFECTS MODULE - ECONOMIC BASE EVALUATION MODEL

The economic base model considers three classes of industry: water-transport-oriented (these are all included in the set of basic industries); other basic sectors (these are industries that are a part of the regional economic base, but are not directly sensitive to water transportation); and the non-basic sectors (which include those in trade, finance, services, and government). In the first phase of the secondary effect module, a set of baseline projections are developed. These projections are based on the assumption that the proposed waterway project will not be implemented. Base year data for the primary study region includes the following:

1. Population
2. Employment by industry
3. Earnings by industry
4. Total personal income
5. Per capita personal income

Growth rates for each data item are determined using the OBERS (Bureau of Economic Analysis, 1981). Then the OBERS growth rates are determined by the computer program and applied to the data for the base year to generate the "baseline" or no-project growth path. The data are reported for the bases year, 1978, and projected to 1990 and 2040. From the projected data, the earnings/employment ratios are determined and stored in the computer program in order to translate earnings change to employment change in the water-oriented sectors.

The transition from the linear programming to the secondary effect module proceeds as follows: the linear programming model predicts output change in each of a set of water-transport-oriented industries. It is assumed that earnings in each sector will change in proportion to the output changes. The earnings/employment ratios, which have been stored, are then used to translate earnings change into employment change in the directly-effected sectors. Employment in the other basic sectors is assumed to be unaffected by the waterway investment.

The ratio of nonbasic-basic activity is assumed to be the same before and after the waterway project is implemented. Thus, the change (Δ) in non-basic earnings and employment is determined as:

$$\Delta E_{NB} = \{E_{NB}/E_B\}_{Baseline} \cdot \Delta E_B$$

where E_{NB} and E_B represent nonbasic activity and basic activity. This employment change is then allocated proportionally among the several nonbasic sectors.

Thus, it is assumed that the ratio of nonbasic to basic activity, whether it be measured in terms of output, earnings, or employment, remains the same under the with-project alternative as it does under baseline projection.

The result is a set of projections for the same year using the same variables as made under the baseline case. The tables are set up in exactly the same format and facilitate the comparisons to be made. That is, for each year being studied, the values of the projected variables on with and without-basis are presented as are the actual change and the percentage change. This facilitates identifying the secondary impacts.

The model uses a static approach. Users must designate the years when the major impact should fall; therefore, the year of direct impact must enter. In this program three years are ear marked 1978 (base year), 1990 (end of project construction), 2040 (end of projection of transportation cost saving impact). The output changes in intervening years must be made by interpolation. The computer interactive program provides the opportunity to enter the base line projection using OBERS data and any assumption imposed on the direct effect module to be represented with the project condition. Any number of appropriate changes can be made by enacting the interactive data check and change procedure of the evaluation system.

At least two simulations using the evaluation model will have to be made in order to obtain estimates of regional impacts under "base" or "without" project conditions and "with" project conditions. There may be additional simulations that will be needed in order to assess the sensitivity of changes in employment, earnings, and population to various cost and/or price, or other parameter changes.

C. THE MODEL OUTPUTS

The model provides industry output, employment and income by industry for two impacted regions for the three different year periods as well as same variables based on with and without the project conditions and their relative percentage changes. The model also provides changes in total population, personal income, employment, per capita income for each impact region and their U.S. relatives.

D. EVALUATION OF CONSTRUCTION IMPACT

The aforementioned model was applied for the measurement of the transportation cost saving impact. The procedure for evaluating the Construction Impact of the project investment takes the following form (Construction Impact Model):

1. Direct impact:

   a) translates construction spending in dollars into a number of job equivalents (by category) based on estimates of direct labor requirement per dollar of spending, proportion of spending within region;

   b) uses the average wage rates by category construction woorkers to determine direct construction impact in the project region.

2. Indirect Impact:

   a) uses job equivalents of direct impact and multiplier to determine job equivalents of secondary construction impact

   b) estimates the earnings using number of jobs and annual wage rate, by job category

3. Total Construction Impact:

   a) estimates non-wage personal income associated with construction activity;

b) estimates total construction impact by adding the direct and indirect impact and non-wage income.

E. INPUT DATA REQUIREMENTS AND SOURCES.

The major input requirements and their sources are as follows:

Input	Sources
Traffic Flows, Transport Cost Identification and Input Uses for basic industries	U.S. Army Corps Engineers Traffic Survey (1981)
Gross Industry Prices for the Basic Industries	Producer Price Series (BLS) Mineral Year Book and Minerals Profiles and Chemical Weekly (B of mines)
Labor and Capital Costs	Annual Survey of Manufacturers value added, value of shipments payroll and employees series (BLS) Census of Minerals Industries Series (B of mines)
The Input Output Coefficents to Represent Production Process	Annual Survey of Manufacturers Census of Mineral Industries Mineral Profiles
Input availability and minimum input demand requirements	Obtained intermediate good information from projected commodity flows
The modal capacity constraints	Projected traffic volumes for the waterway. Modal capacities for non-waterway are assumed to be of that level before the project.

F. EVALUATION OF THE MODEL.

Given the Traffic Survey results and the expenditures from the General Design Manual (GDM) this model is the simplest in theory and implementation. Probably the model may be less expensive. However, the model has some deficiencies compared with two other alternative models. Although the model consists of three regions, the actual evaluation of impact is limited to two

impact regions. There is no consideration of interindustry and interregional structural analysis nor feed back effect among regions including the rest of the U.S. This however, does not prevent the estimation of a rough B/C ratio for the project evaluation. The multipliers, which are the basic machanisms in estimating secondary impacts from transportation cost saving and construction, are not stable ones. One must estimate different types of multipliers depending on the type of impact to be estimated. The supply constraints for the linear programming model is non operative in this model. This means the supply is assumed to be perfectly elastic. This is a serious draw back to the location theory and the LP model itself. The output generated by LP, model is exaggerated in theory.

Appendix I

The Theoretical Exposition of the MVRIO

1. Production Function of an Industry

Consider an economy which has m regions and n commodities. Each industrial output in each region is produced by a Cobb-Douglas production frontier with a constant return to scale in logarithmic form.

$$\ln x_j^r - \alpha_{oj}^r - \sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \ln x_{ij}^{sr} - \gamma_j^r \ln L_j^r - \delta_j^r \ln K_j^r = 0 \qquad (1)$$

$$(j=1, \ldots n;\ r=1, \ldots m)$$

where

x_j^r = output of industry j located in region r;

x_{ij}^{sr} = intermediate purchase of the ith industrial product from region s by industry j located in region r;

L_j^r = labor service employed by industry j located in region r;

K_j^r = service of capital employed by industry j located in region r.

α_{oj}^r, α_{ij}^{sr}, γ_j^r and δ_j^r are parameters of the Cobb-Douglas production frontiers (α_{oj}^r and α_{ij}^{sr} are technology parameters and input elasticity). The linear homogeneity is assumed to be:

$$\sum_{s=1}^{m} \sum_{i=1}^{n} \alpha_{ij}^{sr} \quad \gamma_j^r \quad \delta_j^r = 1 \qquad (j=1, \ldots n;\ r=1, \ldots m) \qquad (2)$$

The supply of output is demanded by industries and final users. The usual balance equations show the market clearing relations; i.e.,

$$\sum_{rj}\sum X_{ij}^{sr} + \sum_r F_i^{sr} = X_i^s \qquad (3)$$

F_i^{sr} is the amount of final demand i produced in region s and delivered to region r. The final demand denotes the commodity delivered to the final users.

2. Optimization of output

The optimum level of output given the price level of output and inputs subject to production technology and market clearing conditions is estimated by:

$$\text{MAX } \Pi = \sum_r \sum_j ((1-t_j^r)\ p_j^{*r}\ x_j^r - \sum_s \sum_i p_{ij}^{sr}\ x_{ij}^{sr} - w_j^r\ L_j^r - v_j^r\ K_j^r) \tag{4}$$

The Lagrangian solutions yield to the following necessary conditions:

$$\frac{\partial F}{\partial x_j^r} = (1-t^r{}_j)\ p_j^{*r} + \phi_j^r \frac{1}{x_j^r} + \gamma_j^r = 0 \tag{5}$$

$$\frac{\partial F}{\partial x_{ij}^{sr}} = -\ p_{ij}^{sr} - \phi_j^r \frac{\alpha_{ij}^{sr}}{x_{ij}^{sr}} - \lambda_i^s = 0 \tag{6}$$

$$\frac{\partial F}{\partial L_j^r} = -\ w_j^r - \phi_j^r \frac{\gamma_j^r}{L_j^r} = 0 \tag{7}$$

$$\frac{\partial F}{\partial K_j^r} = -\ v_j^r - \phi_j^r \frac{\delta_j^r}{K_j^r} = 0 \tag{8}$$

$$\frac{\partial F}{\partial \phi_j^r} = \ln x_j^r - \alpha_{oj}^r - \sum_s \sum_i \alpha_{ij}^{sr} \ln x_{ij}^{sr} - \gamma_j^r \ln L_j^r - \delta_j^r \ln K_j^r = 0 \tag{9}$$

$$\frac{\partial F}{\partial \lambda_i^s} = x_i^s - \sum_r \sum_j x_{ij}^{sr} - \sum_r F_i^{sr} = 0 \tag{10}$$

p_j^{*r}, w_j^r and v_j^r denote respectively the producer price, wage rate and the service price of capital of industry j located in region r. t_j^r is an effective tax rate for industry j located in tegion r. p_{ij}^{sr} is the purchase price of input i produced in region s and purchased by industry j located in region r.

ϕ_j^r and λ_j^r are the Lagrangian multipliers of the jth production frontier and the ith balancing equation in region r and region s respectively.

From Equation (5)

$$\phi_j^r = -\ (1-t_j^r)\ p_j^r\ x_j^r \tag{11}$$

where

$$p_j^r = p_j^{*r} + \frac{\lambda_j^r}{(1-t_j)}$$

p_j^{*r} is an exogenously determined producer price of the commodity j in region r. There is no guarantee that this price could clear the market. The Lagrangian multipliers (λ_j^r) is the additional price which ensures the market clearing condition. p_j^r is the equilibrium price of the commodity j in region r. Since λ_j^r is unknown, the equilibrium price is unknown and is to be solved from the model.

The input purchase price of p_{ij}^{sr} is determined by

$$c_{ij}^{sr} \cdot p_i^s = p_{ij}^{sr} + \lambda_i^s \tag{11a}$$

As in the case of producer price (p_j^{*r}), there is no guarantee that these input purchase prices will clear the markets. The shadow price λ_i^s is the additional price which insures market clearing conditions.

The equilbrium price (p_i^s) multiplied by the transportation cost factor (c_{ij}^{sr} = 1 + percentage of transportation cost per a dollar sale) are assumed to be equal to the market clearing prices.

The input purchase price (p_{ij}^{sr}) varies from region to region because of differing degress of the transportation cost factor (c_{ij}^{sr}). Linehaul, terminal, and time cost constitute the transportation cost. Interest income lost during the shipping period was considered as a proxy to the time cost.

3. Demand for inputs in terms of equilibrium prices

Equations ((6), 7), (8), (11), (11a) provide the profit maximizing intermediate inputs (x_{ij}^{sr}), labor input (L_j^r), and capital service (K_j^r) in terms of the equilibrium prices (p_j^r);

$$x_{ij}^{sr} = \alpha_{ij}^{sr} (1-t_j^r)\ p_j^r\ x_j^r/(c_i^{sr}\ p_i^s) \tag{12}$$

$$L_j^r = \gamma_j^r (1-t_j^r)\ p_j^r\ x_j^r/w_j^r \tag{13}$$

$$K_j^r = \delta_j^r (1-t_j^r)\ p_j^r\ x_j^r/v_j^r \tag{14}$$

4. Equilibrium Price Equation (Frontier)

By substituting demand for inputs in production equation (1) by inputs demand in terms of equilibrium prices (p_j^r) the multiregional price frontier equation was obtained:

$$\ln p_j^r = -\alpha_{oj}^r - \Sigma\Sigma\, \alpha_{ij}\, \ln\alpha_{ij}^{sr} - \gamma_j^r \ln\gamma_j^r - \delta_j^r \ln\delta_j^r - \ln(1-t_j^r)$$

$$+ \Sigma\Sigma\, \alpha_{ij}^{sr} \ln c_i^{sr} + \Sigma\Sigma\, \alpha_{ij}^{sr} \ln p_i^s + \gamma_j^r \ln w_j^r + \delta_j^r \ln v_j^r = 0$$

$$(j=1, \ldots n;\ r=1, \ldots m) \qquad (15)$$

The price frontier equation (3-15) can be conveniently presented as a matrix:

$$(I - S)\ \ln p = h \qquad (16)$$

where

$$\underset{(nm,nm)}{S} = \begin{bmatrix} \alpha^{11} & \cdots & \alpha^{m1} \\ \vdots & & \vdots \\ \alpha^{1m} & \cdots & \alpha^{mm} \end{bmatrix} \quad \underset{(nm,1)}{\ln p} = \begin{bmatrix} \ln p \\ \vdots \\ \ln p^m \end{bmatrix} \quad \underset{(nm,1)}{h} = \begin{bmatrix} h^1 \\ \vdots \\ h^m \end{bmatrix}$$

and

$$\underset{(n,n)}{\alpha^{sr}} = \begin{bmatrix} \alpha_{11}^{sr} & \cdots & \alpha_{n1}^{sr} \\ \vdots & & \vdots \\ \alpha_{1n}^{sr} & \cdots & \alpha_{nn}^{sr} \end{bmatrix} \quad \underset{(n,1)}{\ln p_1^r} = \begin{bmatrix} \ln p^r \\ \vdots \\ \ln p_n^r \end{bmatrix} \quad h^r = \begin{bmatrix} h_1^r \\ \vdots \\ h_n^r \end{bmatrix}$$

I is an (n.m) by (n.m) identity matrix.

h_j^r is the sum of all variables except the price variable; i.e.,

$$h_j^r = -(\Sigma\Sigma\, \alpha_{ij}^{sr} \ln\alpha_{ij}^{sr} + \gamma_j^r \ln\gamma_j^r + \delta_j^r \ln\delta_j^r) - \alpha_{oj}^r$$

$$+ \Sigma\Sigma\, \alpha_{ij}^{sr} \ln c_i^{sr} - \ln(1-t_j^r)$$

$$+ \gamma_j^r \ln w_j^r + \delta_j^r \ln v_j^r \qquad (17)$$

By simultaneously solving the price froniters (16), the nm profit-maximizing price level was obtained in terms of the transportation cost, effective tax rate, local wage rate, service price of capital, input elasticity (α_j^{sr}, γ_j^r δ_j^r) and the technical progress parameter; i.e.,

$$p_j^r = p_j^r\ (c_i^{sr},\ t_j^r,\ w_j^r,\ v_j^r,\ \alpha_{ij}^{sr},\ \gamma_j^r,\ \delta_j^r,\ \alpha_{oj}^r) \tag{18}$$

5. Estimation of Input-Output (Technical and Trade) Coefficients

Technical coefficients a_{ij}^{sr} are expressed in terms of the equilibrium prices, effective tax rates, and the transportation cost;

$$a_{ij}^{sr} \equiv \frac{x_{ij}^{sr}}{x_j^r} = \alpha_{ij}^{sr}(1-t_j^r)\ \frac{p_j^r}{c_i^{sr}\ p_i^s} \tag{19}$$

a_{ij}^{sr} is function of the same variables to determine equilibrium prices i.e.

$$a_{ij}^{sr} = a_{ij}^{sr}\ (c_i^{sr},\ t_j^r,\ w_j^r,\ v_j^r,\ \alpha_{ij}^{sr},\ \gamma_j^r,\ \delta_j^r,\ \alpha_{oj}^r) \tag{20}$$

Applying Moses (Moses 1955) definition of regional technical coefficient a_{ij}^{sr} can be expressed in terms of the trade coefficient (t_{ij}^{sr}) and the regional technical coefficient; i.e.,

$$a_{ij}^{sr} = t_{ij}^{sr} \cdot a_{ij}^r \qquad (i,\ j=1,\ \ldots n;\ s,r=1,\ \ldots m) \tag{21}$$

where

$t_{ij} = t_i^{sr}$ and $a_{ij}^{sr} = \sum_{s=1}^{m} a_{ij}^{sr}$ are assumed.

From $a_{ij}^{sr} = t_{ij}^{sr} \cdot a_{ij}^r$ a trade coefficient t_{ij}^{sr} is estimated by $t_{ij}^{sr} = a_{ij}^{sr}/a_{ij}^r$ since a_{ij}^r is variable, t_{ij}^{sr} is also variable coefficient and function of

$$t_{ij}^{sr} = t_{ij}^{sr}\ (c_i^{sr},\ t_j^r,\ w_j^r,\ v_j^r,\ \alpha_j^{sr},\gamma_j^r,\ \delta_j^r,\ \alpha_{oj}^r) \tag{22}$$

Both technical and trade coefficients has been derived from the dual relationship between the production and price frontiers.

6. Determination of Labor and Capital Coefficients

Similarly, the labor coefficient (L_j^r/x_j^r) and the capital coefficient (K_j^r/x_j^r) are obtained.

$$L_j^r/x_j^r = \gamma_j^r \ (1-t_j^r)p_j^r/w_j^r \tag{23}$$

$$K_j^r/x_j^r = \delta_j^r \ (1-t_j^r)p_j^r/v_j^r \tag{24}$$

So far, the system solved equilibrium prices $(p_j^r = p_j^{*r} + \gamma_j^r/(1-t_j^r))$, regional input-output coefficients $(a_{ij}^{sr} = x_{ij}^{sr}/x_j^r)$, trade coefficients (t_i^{sr}), labor coefficients (L_j^r/x_j^r), and capital coefficients (K_j^r/x_j^r).

7. Determination of Regional Output (x_j^r)

Regional output (x_j^r) is determined by the balance equations (3) with given final demand shipped (F_i^{sr})[1]. F_i^{sr} denotes amounts of the commodity i produced in region s and shipped to the final demand account in region r.

The final demand shipped (F_i^{sr}) may be expressed in terms of the final demand received (y_i^r) which have the following relations.

$$F_i^{sr} = t_i^{sr} \ y_i^r \tag{25}$$

Given the final demand vector and the balance equation (3) provide the output equation,

$$x = (I - TA)^{-1} \ Ty = (I - TA)^{-1} \ F \tag{26}$$

where:

F = Ty, T and y denote final demand shipped and received respectively; I, T, a are an idenity matrix of a trade coefficient matrix and a regional technical coefficient matrix.

x, F and y are n.m component vectors of regional output and regional final demand, respectively.

T and A are n.m by n.m matrices of the trade coefficeint and the regional coefficient.

This balance equation solves the industrial output (x_j^r) which identifies all profit maximizing input demands (x_{ij}^{sr}), labor input (L_j^r), and the service price of capital (K_j^r).

Using the income and employment coefficients the same balance equation can provide the changes in income and employment accompanying the change in output due to changes in cost and spending. The solution also provides output, income, employment and price multipliers and trade structures.

A change of industrial output (Δx) can be expressed as a change of TA $\{\Delta(TA)\}$ and a change of the final demand (ΔF). i.e.,

$$\Delta x - \Delta(TA)x - (TA)\ \Delta x = \Delta F \quad \text{and} \tag{27}$$

$$\Delta x = (I - TA)^{-1}\ \{\Delta(TA)\ x\} + (I - TA)^{-1}\ \Delta F \tag{28}$$

where

$(I - A)^{-1}\ \{\Delta(TA)\ x\}$ is the substitution effect which is the change in the output due to the changes in costs.

$(I - TA)^{-1}\ \Delta F$ is the income effect which is the change in the output due to the change in spending.

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