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FISCAL ALLOCATION AND WATER FEES STUDY

Completion Report
Phase I

Dames & Moore
Utah State University

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EXECUTIVE SUMMARY

In 1972, the Republics of Mali, Mauritania, and Senegal joined in establishing the Organization pour la Mise en Valeur du Fleuve Senegal (OMVS) with the main objective of implementing common projects. To this end, it was decided to construct the Diama and Manantali dams for the purpose of providing three services:

- Increased water supply for irrigated agriculture and other demands.
- Water impoundment for hydroelectric power generation.
- Stabilization of river flows for navigation.

Whereas Diama will provide the first service in addition to its salinity barrier function, Manantali will generate all three services. These services will be consumed by three basic user categories (use sectors):

- The agricultural sector.
- The industrial sector (mining, transportation, etc.).
- Other tertiary sectors (urban, domestic, etc.).

However, the development of a shared river basin which takes into account the specific goals of all use sectors and countries is a complex and risky venture. Decision tools are needed to equitably and efficiently apportion project services, allocate costs, determine responsibilities for repayment of loans among the participating member states.

The most delicate problem is the allocation of costs which determines the quotas, or percentages, of the reimbursement of the debt contracted for the development of the project.

The basis of these quotas must be clear to all parties. It is not sufficient to simply determine the shares of repayment responsibility; the basis of the allocation must be justifiable and shown to be equitable. Therefore, it is necessary to find a simple and flexible methodology for allocating the costs which is acceptable to each member state.

To that end, and in cognizance of the importance of the problem, the Council of Minsters of the OMVS commissioned a series of studies on the allocation of project costs among services and countries.

In 1974, pursuant to the OMVS Council of Ministers' Resolution Number 25/74/CM.S.D., Utah State University was contracted to review the various methods of cost allocation by service and by country. Based on the Separable Cost-Remaining Benefits (SCRB) method, programming of the "Fiscal Allocation and Management" model (FAMM)[1] was initiated. The SCRB method had been developed by water resource development agencies in the United States and was considered, at that time, to be the most acceptable cost allocation method. In 1977, Loughlin (1977) proposed an adjustment to the SCRB method, called the Adjusted Separable Cost-Remaining Benefit method (ASCRB).

The ASCRB method was recommended to the Council of Ministers and adopted in 1981 (Resolution Number 143/CM/SN/D(81). It was used to generate the first allocation "key." The "key" provided the cost proportions of the Diama and Manantali dams to be allocated to each member state for each service. It assigned the responsibility for repayment of the debt contracted for program development according to the following percentages: 46.64 percent to Senegal, 36.95 percent to Mali and 16.96 percent to Mauritania.

In 1986, a UNDP-funded study[2] in support of the OMVS Council of Ministers' Resolution Number 188/CM/MN/N(85) was undertaken to present and evaluate scenarios for revising the key on the basis of new data and a modified distribution of the Manantali-generated hydroelectricity. The FAMM model was expanded to include environmental costs and a loan management module. The same allocation method was retained, and a new key was calculated and adopted by the Council of Ministers at its 25th Ordinary Session held in Dakar (Resolution Number 197/CM/SN/D(86)). The study also identified the need for further analyses and special requirements for reprogramming the FAMM model.

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[1]The programming of the Fiscal Allocation and Management model was initiated in 1974 under Contract ADO-Dakar/OMVS-3 between the OMVS and Boeing Services International Inc. The model was subsequently presented in a "Final" report dated August 1978, entitled "Cost Allocation Alternatives for the Senegal River Development."

[2]The study was funded by the UNDP under its RAF/81/059 project.

The model was, however, found to be insufficient for resolving the problems of cost allocation in that its programming support was cumbersome, there were difficulties in its utilization, and the data base was not sufficiently detailed.

Thus, at its 26th Ordinary Session in Dakar in April, 1987, the Council of Ministers requested that an in-depth study of methods of allocation be undertaken and that the FAMM model be made operational on personal computers at the OMVS offices in Dakar. In addition, they requested an analysis of the retroactive application of changes in the key.

Four general methods have been identified:

- Methods based on physical utilization of the common works, which do not take account of benefits resulting from the services an can cause economic in efficiencies and inequities (costs may be allocated in excess of benefits). These methods are simple and easily programmed on personal computers (PCs).
- Methods based on total benefits, of which the ASCRB method is the most appropriate, and has been used in the FAMM model. This method does not account for marginal benefits and costs, but appears to be the most appropriate for the OMVS program. It can be easily programmed in a single, easily used model.
- Methods based on marginal benefits and costs, of which the most appropriate is the inverse elasticity pricing (IEP) approach. This method is theoretically the most economically efficient, but may be more adapted to setting tariffs (pricing and cost recovery) than to cost allocation. The method requires a combination of sophisticated programming techniques, and users would be required to have adequate training in optimization and econometric techniques. Data requirements would be significantly greater than with total benefit methods.

- The Average Benefit Method (ARB). This method is a compromise between the ASCRB and IEP methods. It could be programmed in a single, user-friendly model on PC's and use approximately the same data as the ASCRB method. However, the method accounts only partially for marginal benefits and costs, and it cannot guarantee that criteria for equity and efficiency will be met.

On the basis of a comparative analysis of these methods, only the ASCRB method appears to be appropriate for allocating costs among member states on an efficient and equitable basis.

All three methods would allow for a recalculation of the key as conditions change. However, the key is a planning instrument and an aid in decision-making. Its retroactive application is <u>not</u> recommended since it is not justified given the reimbursement conditions set forth in the agreements establishing the OMVS (Conventions Relative au Financement des Ouvrages de Base de l'Organisation). Further, the costs associated with the retroactive application appear to be much greater than benefits gained from it, given the problems of accounting and compensatory payments and the uncertainty generated by it in the planning process and the development of the Basin.

The reprogramming of the FAMM model will allow the inclusion of a financial model which will serve to analyze the payments and obligations of users of services and determine the reimbursement payments necessary for the repayment of the loans incurred by OMVS on behalf of the member states. However, this financial model is not meant to serve as a day-to-day financial management tool.

SYNTHESIS REPORT

The main purpose of integrated river basin development is to make the best use of scarce resources to promote long term socio-economic development. In the case of the Senegal River Basin, this objective can be obtained only with joint development of the river, including consideration of the physical constraints, the environment, and the hydrology of the basin. Joint development allows the riparian countries to obtain greater benefits than would be possible in the absence of cooperation. However, this entails resolution of a number of issues, among which are conceptualization and planning, management of the structures, and allocation and sharing of repayment responsibilities with respect to debt servicing.

The Senegal River Development program was conceived with these goals in mind. It was financed from different sources and produces multiple services which are unequally consumed by the three countries. The organization which was developed to plan and construct the project (OMVS) will not be responsible for the repayment of loans. This responsibility falls upon the member states as sovereign powers. Thus, an easily understood and flexible method for determining the loan repayment responsibility was required.

From 1972 to 1976, Utah State University (USU) studied the cost allocation problem to help in the planning and decision making processes.

Initially, USU identified possible methods for allocating costs to help the OMVS supervisory body, the Council of Ministers, select the most appropriate methodology. The results of this study can be found in Report 1 (Utah State University, 1978). Originally, a computer model for the cost allocation (the FAMM model) was developed for use on mainframe computers available at USU. This model was used to develop the first "key" adopted by the Council of Ministers in 1981 (Resolution Number 143/CM/SN/D(81)).

In 1983-1984, the FAMM model was adapted for use on Digital PDP 11/23 computers which were provided to the OMVS. Using the ASCRB method, this computer program allocated project costs to the various services concerned [irrigation water, energy

(hydropower), and navigation]. The computer model then allocated the service costs to each country based on the level of use. In Report 6 (Utah State University, 1984), details of the program and its use are provided.

In 1986, the data in this model were updated and the model was expanded to include some environmental costs and a module which dealt with loan repayment scheduling. The same allocation method was retained, and a new allocation key was calculated to take account of a new division of the use of energy and presented in Report 7 (Utah State University, 1987).

However, the FAMM model did not meet all the needs of the OMVS, relative to sensitivity analyses, usability, and consideration of microeconomic impacts of tariffs on users of project services.

Thus, at their 26th regular session (held in April, 1987), the Council of the Ministers, for the purpose of establishing cohesive policy guidelines, requested a study be carried out to provide more information on the methods for allocating project costs among countries, to evaluate the implications of retroactive application of the key, and to refine and adapt the FAMM model for use on personal computers.

The present study, undertaken by USU under a subcontract from Dames & Moore titled the "Fiscal Allocation and Water Fees Study," (PDP 625-0621) constitutes a response to such a request. This report attempts to meet the identified objectives, namely:

- To identify and recommend methods for allocating project costs among the countries -- the calculation of a "more equitable key."
- To reprogram the previous FAMM on IBM System/2 PCs and make it easily accessible to the OMVS personnel.
- To examine the implications of a retroactive application of the key.

This completion report for Phase I of the study was prepared to furnish the BASIS on which the Council of Ministers can choose an appropriate cost allocation method and examine the question of retroactive application of the key.

Cost Allocation Among Countries

The first objective of this report is to provide the OMVS with information about cost allocation methods for its member states. The allocation of costs is one of the critical elements in the realization of program objectives. Its political and socio-economic implications make the problem particularly difficult in the context of periodic and persistent droughts in the member states.

In the Senegal River Basin development program some sectors that use the services provided by the Manantali and Diama dams may be only partially responsible for the repayment of project costs. A given country may opt to provide subsidies to some services using external sources of funds for repayment, in order to encourage national development, for redistribution of income, or as a result of the public-goods nature of some sectors. Thus, the responsibility for reimbursement of the costs must be assigned to each of the member states due to the sovereignty of each state. Such a system for allocating the project costs must reflect economic efficiency and equity.

The new (1978) common works convention (replacing the 1972 convention) only partially elaborated on the principles and issues needing settlement with respect to repayment responsibility. The convention stipulates that "rights and obligations shall be based on equality and equity" (Article 11); "investment and operating costs are to be allocated among the member states on the basis of the benefits each state derives from the projects. This cost allocation based on the operating result of the whole regional infrastructure system can be readjusted periodically as a function of the results of project utilization, and any readjustment agreed upon by the member states will have no retroactive effect on previous repayments" (Articles 12). In addition, the convention indicates that "the member states guarantee the reimbursement of the principal, interest and other charges of loans contracted by the Organization for construction of the common works" (Article 13). However, they did not indicate any methods for applying these principles or sharing the cost of the project services.

The necessity for allocating project costs arises from the fact that the sum of the direct costs associated with each of the services are not equal to the total project costs; each service requires at least a portion of these common works.

Questions of equity and economic efficiency in the utilization of resources in the basin are the basis for allocating a fair share of the repayment responsibility. There are four basic approaches to cost allocation:

- Physical measures of utilization
- Total benefits
- Average benefits
- Marginal benefits

These different options as well as their theoretical and methodological bases, and calculation procedures are presented in detail in Appendices I and II, with an example presented in Appendix IV.

- *Allocation by physical measures.* Among the variants of this method, the utilization of services appears to be the most acceptable; however, because this approach ignores benefits generated by the services, it is acceptable only if the benefits to a given service are the same for each country. When productivity differences among regions are considered, allocation by use of service becomes economically inefficient. Differences in benefits among users of a service could not be taken into account with this method.
- *Allocation by total benefits.* In this option, the total benefits accruing to a project service in each country are used as a cost allocation basis. There are three alternatives under this option: the total benefits, the remaining benefits (SCRB), and the adjusted remaining benefits (ASCRB).

ASCRB has been acknowledged as the best among these three total benefit methods. It would also be consistent with the allocation of costs among services in earlier allocation studies, but ASCRB does not consider marginal values.

Allocation by total benefits can be applied in a single, user-friendly, menu-driven model. It can be easily used by people who are relatively unfamiliar with the theory of cost allocation or sophisticated empirical techniques. Data requirements would be considerable, but sophisticated data manipulation would not be necessary.

- *Allocation by marginal benefits.* There are two possible methods in this category: inverse elasticity pricing (IEP) and full optimization.

The IEP method is based on the elasticity of demand for services; that is, the sensitivity of demand of service users to variations in the price of the service is used to determine the allocation. But, demand curves need to be developed for services in each country using statistical or optimization techniques. These curves are used to maximize the welfare function (consumers' plus producers' surplus) subject to the constraint that the total revenues from project services must equal total allocated project costs. This nonlinear optimization will generate the optimal "price" and the optimal use for each service for each country. The "key" would be obtained based upon these optimal "prices" and quantities.

Although this method is theoretically attractive, the optimal values generated are artificial, and may not be related to actual levels of use. Furthermore, different "prices" could be charged for the same service in different countries.

IEP requires a combination of mathematical optimization (with commercial programs such as LINDO, GAMS, etc.) and statistical program packages (such as TSP, SASS, etc.) for generating the demand curves and calculating the key. Data would have to be transferred from one program to another, and users would need to have extensive training in cost allocation theory and the required software.

The required input data would be greater and substantially more detailed than with the previous FAMM model. Currently, data are not available on the use of irrigation water at various prices. A variety of farm budgets would need to be developed to estimate the marginal value of water in agriculture. Navigation presents a more difficult problem. Users' budgets or willingness to pay are more conjectural and based upon less concrete data.

Both energy and navigation services are to be used by irrigators. Because inverse elasticity prices would be determined for both services, the "prices" for irrigation water, energy, and navigation would be interdependent in the model. Further constraints on one price or the other would be necessary to obtain a given optimal solution. A range of optimal solutions would have to be generated.

Cross-subsidization among countries may result if IEP is applied to the overall cost allocation process for the OMVS program.

The other alternative method is full optimization. It would maximize total net benefits to the OMVS program and would generate shadow values (implicit prices) for water. These shadow values would indicate the marginal value of the water.

It would be impossible, however, to include each year of the time horizon in a PC optimization model. The existing PC optimization routines limit the size of the model; thus, aggregated data must be used.

For PC implementation, optimization would have to be nonstochastic and would have to consider only average (expected) values for all prices, costs, and water availabilities. Under the average conditions for the Senegal River Basin, the shadow value for water will be zero, or very close to zero since there will be sufficient water to provide for full development of all services. A zero shadow value means that the provision of extra units of water, or transfers of water among users, will not change total benefits. A cost allocation to countries cannot be made using such shadow values.

Furthermore, total repayment of costs will occur automatically only if the sum of the marginal costs of services reflects all the project costs. Where joint production is involved, the marginal costs do not include the costs of the joint facilities. A constraint requiring that all costs must be repaid would have to be included in the model. That constraint forces the "prices" determined by full optimization (the shadow values) to deviate from the marginal costs (the IEP).

The theoretical and empirical problems associated with full optimization indicate that such an option should not be used.

- *Allocation by the average benefits.* This alternative is a compromise between the allocation by the total benefits and allocation by IEP. The average remaining benefit is an approximation of the midpoint of the demand curve for a service in a given country. Marginal benefits would be partially considered; however, this method cannot guarantee that the criteria for economic efficiency or equity will be satisfied.

The average remaining benefits method can be easily implemented on microcomputers in a user-friendly model. All calculations, including the key, can be completed with a single model using data similar to the ASCRB method.

Conclusion

Economic efficiency, equity, and ease of implementation are the main criteria to be considered for the selection of a given option. Table 1 lists the advantages and disadvantages of each method.

In view of the comparative analysis which has been undertaken, we recommend that the ASCRB method be used for the allocation of costs among services and countries for the OMVS program.

Table 1: Advantages and Disadvantages of the Different Methods

Methods of Cost Allocation to Country	Advantages	Disadvantages
Utilization of Facilities - Equal among the sectors - Proportional to the degree of use of facilities - By Priority	• Simple to program • Easy to use by untrained individuals • Minimal data base	• Economically inefficient • Inequitable and does not take into account the differences in benefits to users • Does not take account of marginal benefits and costs
Total Benefits - Net benefits - Justifiable Costs -SCRB - ASCRB	 • Easy to program • Doesn't require trained personnel • Minimal data base required • Satisfies the criteria for economic efficiency • Conforms to the methods used in past allocations • Same advantages as SCRB and is more equitable	 • Economically inefficient and inequitable • Does not consider marginal benefits or costs • SCRB not equitable (credit for cost savings in the common works) • Problems may occur with cross-subsidization •Not based on the marginal values
Average Benefit (ARB)	• Takes partial account of marginal benefits and cost • Can be programmed in a user-friendly model • Requires a minimum of data	• May fail the tests of economic efficiency • Ignores most of marginal costs and benefits
Marginal Benefits -IEP	• Economically efficient • Takes full account of marginal benefits and costs • Equitable	• Can not be modeled in a single, user-friendly model for untrained user • Requires good knowledge of the theory of optimization and programming • Not suited to cost allocation given actual use of services
- Global Optimization	• Economically efficient and equitable • Takes count of marginal benefits and costs	• Very difficult to program on PCs • Requires extensive data • Does not insure full repayment • Problems of dimensionality

Reprogramming the FAMM Model

The present study was also initiated to resolve problems encountered in the use of the FAMM model, which had been identified by several authors. A complete description and discussion of the FAMM model can be found in Appendix III.

1. Methods and Support

Originally, the FAMM model was a computer program developed to apply the ASCRB method to the Senegal River Basin program. It was written in Fortran code for execution on IBM and Digital Vax mainframe computers at USU in 1975-1976. It was used in an extensive sensitivity analysis from 1976 to 1978 for allocation methods for the three project services: irrigation, hydroelectric power, and navigation.

In 1982, the OMVS Council of Ministers requested a transfer of the program to Dakar and an upgrading of the data base. Digital PDP 11/23 computers were provided to the OMVS, and the FAMM model was reprogrammed in DEC-Based Fortran (USU Report 6 presents a comprehensive description of the model). In the course of the programming, the model was expanded to include environmental costs and a sub-model for loan management activities. Then, in 1986, another update of the FAMM model was financed by UNDP (Utah State University, Report 7, 1987) to take account of a new data base and a new distribution of hydropower from Manantali among the member states.

2. Weaknesses of the Model

In spite of the various modifications made to the FAMM model, GIBB/EDF/EC (1986), and others, have identified certain weaknesses in it, notably:

- The model did not apply to the actual [financial] situation, and the accounting sub-model could only be applied in a macroeconomic context. This criticism is valid. The documentation was not clear about the use of the model. The model was not intended to allocate costs on a financial basis; it was an economic analysis. Also, the nature of the loan management sub-model was not clearly stated in the users' manual. It was used only to determine the

interest charges on the loans; it was not meant to serve as an accounting package for OMVS. The result was misinterpretations of the model as a financial tool.

- The model, as well as the documentation contained in the users' manual, were difficult to understand and to use. The constraints inherent in the programming of the FAMM model led to some of these problems.
- The model did not provide for a single uninterrupted "run" from the input of data to the calculation of the key, and its programming failed to provide easily used French menus or directions.
- The key was calculated separately from the model and required the user to enter the data manually.
- There was no explicit water balance in the model. The FAMM model did not print out a water balance for two reasons: 1) the model assumed a single, homogenous region from Manantali Dam to Diama Dam, and 2) studies by GIBB/EDF/EC, ORSTOM, USU, and others indicate that the average annual availability of water was sufficient for full project development. However, the model did calculate diversion and consumptive use by crop.
- The model did not account for microeconomic impacts of tariffs or the capacity of users to pay for services.

Proposed Solutions

In order to correct these shortcomings, to following model reprogramming is proposed:

- Change in computer systems and programming. The model will be menu-driven in French, more user-friendly, and better adapted to the current conditions. Since the PDP 11/23 computers are no longer functional, IBM System 2 PCs have been provided to the OMVS which are compatible with

the organization's existing equipment and skills. The model will utilize Microsoft C as the programming language which will facilitate the interfaces of data base software and French menus.

- An explicit water balance will be included as part of the model. This water balance will consider water releases from the Manantali Dam, diversions along the river in each region, consumptive use and return flows, and the outflows from the upstream regions to the downstream regions. To be consistent with the rest of the allocation process, the model will be based on average annual water availability. It does not appear that the average annual availability will constrain the services (GIBB/EDF/EC, 1987).
- New use sectors will also be included such as municipal and industrial (M&I) water supplies and alternative uses of energy. It will specify regions and farm types, and the livestock production data will be re-examined.
- A financial model will be developed. The general criticism of the FAMM model was that the microeconomic impact of repayments, particularly concerning tariffs and actual ability to pay of users of project services, was not taken into account. While the cost allocation is not meant to provide a financial analysis, the ability of users to pay for the project is a critical issue, particularly given the current economic crisis and financial problems with which the member states are faced.

Consequently, the objective of the financial model to be developed in Phase II of the present study will be to test different approaches which can be utilized to examine the microeconomic impacts of repayment and the management of the loans. This model will be composed of two parts: a model to perform a microeconomic analysis and a model for examining loan management.

The microeconomic model should analyze the users' ability to pay for project services through optimal tariffs. The approach will be based on a simple inverse elasticity model

using financial data. If the data limitations preclude this approach, a simulation model based upon accounting processes will be developed.

The model for loan management will permit the determination of loan repayments for each member state. The difference between the revenues generated by the tariffs established in the microeconomic model and the reimbursements required will determine the contribution required of each member state.

No matter which approach is taken, it is unlikely that the model will be "user friendly" or easy to use. The precision required will make the programming and data bases very complex.

Retroactivity of the Key

The Council of Ministers, at its 26th Ordinary session in Dakar in April 1987, decided to convene an ad hoc meeting of experts from the member states as well as the High Commission. The Council requested that the High Commission study the consequences of adopting the principle of a retroactive application of the cost allocation key for the jointly owned structures, taking into account:

- Modification criteria for the key.
- Timing of retroactivity.
- Implications of retroactive application of the key including the frame, mechanisms, and practical modalities of the necessary compensatory payments.
- Eventual impacts on the development of the Basin.
- Amendments to the organization's basic texts on these issues.

This retroactivity section of the report was developed to respond to their request.

It first must be recalled that, up to now, new keys have been applied only from the date of the adoption. Article 21 in the agreements among the member states in the creation of the OMVS (Convention Relative aux Modalities de Financement des Ouvrages Communs) stipulates that: "the share of the participation of each member state of the OMVS in the costs and expenses of the common works may be readjusted by common accord among the member states. In such a case, the sums owing before the date at which the readjustment becomes effective remains due from each member state. Only the balance of the payable loans to term after the date must be modified according to the new key."

The same Convention, however, stated that (Article 11), "the contributions made to the Organization by the co-guaranteeing States under the title of service of the debt represent advances made to the Organization by the co-guaranteeing States. These must be reimbursed to the co-guaranteeing States as the resources of the Organization permit."

A priori, one can consider, following that logic, that the reimbursements will take into account the duration of these "advances" and the conditions (economic, financial, etc.)

existing when the agreement was made. Thus, the application of the principle of retroactivity from the time of adoption of a new key is not necessary. Each member state will be reimbursed equitably, according to the advances which it has made to the Organization.

With these considerations in mind, building a consensus and providing for economic efficiency, equity, and incentives which are likely to stimulate effective cooperation among the three member states, the allocation key should be periodically recalculated. Each country's fair share of the repayment responsibilities can be more accurately indicated in a new key. There should be a method for updating the key because the common investments which the member states have made are based upon the feasibility studies. These studies are, in turn, based primarily upon projected economic benefits.

However, actual performance is seldom the same as even the best projections. Parameters such as operating and maintenance costs, commodity prices, rates of development, and use of services could differ substantially from the projections. The initial cost allocation based on the projections is only a first step. There must be a method for adjusting the difference between projections and actual performance.

1. Criteria for modification of the key.

Theoretically, only computer technology limited the frequency of recalcualtion of the key. However, the frequency will realistically be controlled by practical considerations, such as the availability of statistical data and economic forecasts, the difficulty in collecting information, and the cost of applying the new key to the loan repayment process. At this point, it is impossible to estimate the practical frequency of recaiculating the key, but the cost would be justifiable when:

- The difference between forecasts and actual data becomes larger than some pre-established threshold. The value of this threshold should be the result of very careful study. Its application should entail constant monitoring and periodic variance analyses.

- Major investments are made which will materially alter the benefits to member states.
- Political considerations lead to a decision to recalculate the key.

However, it is important to clearly understand the basis on which a new key is calculated.

A new key reflects a new historical period, and, consequently, it includes the actual circumstances from the project's initiation. Several questions arise regarding the application of a new key. Should a new key (which more accurately reflects the economic history of the project) be applied retroactively? If the answer is "yes," for which period should it be applied? Should the new key be applied retroactively going back to project start-up, or should its application cover an intermediate period, such as the time elapsed between the last and current calculations of the key? What would be the consequences?

2. *Timing of retroactivity.*

Possible choices for the period of retroactivity are discussed below:

- *Retroactivity from the date of the first investment(s).* In this case the procedure conforms to the cost allocation analysis in that the entire stream of benefits and costs are considered in the cost allocation. However, this approach poses accounting problems, particularly when changes occur in the key near the end of the time horizon. In this situation, even small changes in the proportion of repayment responsibility for a member state could cause relatively large changes in the total amount of the repayment responsibility for that state.
- The risk associated with retroactivity could require that member states either maintain sufficient capital reserves to meet contingencies, or make compensatory installment payments. With installment payments, the key could potentially change faster than the completion of the past compensatory obligations. Thus, the accounting problems could become increasingly complex and burdensome.

- *Retroactivity from the date of the last revision of the key.* The choice of retroactivity from the last key revision could reduce some of the complexity of the accounting problems. Changes in the key would be applied to a limited time frame, under a fixed schedule. New and old repayment shares (as determined by the key) would be multiplied by the total, or annual repayments, over the period from the last change in the key. The difference between the two figures would be the compensatory payments. However, if compensatory payments from the previous recalculation of the key (for example, from five to ten years in the past) were still outstanding, multiple payments from member states could result.
- *Retroactive application of the key over two or more revision periods.* As in the two previous cases, accounting problems associated with this option would be burdensome to the OMVS and to the donors (if any) who might have pledged to participate. Additionally, the longer the retroactive period, the larger would be the potential adjustments which a member state could be required to meet.

3. *Consequences of Retroactive Application of the Key.*

- *Complexity of the accounting process.* The more frequent the adjustments of the key, the smaller would be the compensatory payments for a particular period. However, because of the increased possibility of overlapping intercountry obligations, the complex problem of interest payments could be magnified.
- *Uncertainty.* Retroactivity will clearly increase uncertainty in the planning process within the member states regarding the payments already made. Because the repayment shares derived from the key are calculated using ratios of remaining benefits, no member state could be certain that its past payments were adequate to meet past repayment requirements. Even if benefits in one member state were less than projected (for the past key), its payments could

be increased because the benefits to the other member states could be proportionately even lower. For any expected value of benefits, the variability of allocated costs would be greater by the amount of variability associated with uncertain past obligations.

- *Reduced flexibility.* Because of the economic uncertainty associated with the retroactive application of the key, other potential development projects could conceivably be threatened. One of the reasons for developing the Senegal River Basin was to create general economic growth through increased physical and financial capital stocks. With at least part of the financial capital stocks reserved for repayment, growth could be retarded, and financial capital stocks could be inefficiently allocated.
- *Irrelevance of sunk costs to decision-making about future actions.* Economic analysis generally regards sunk costs (costs which have already been incurred) as irrelevant to decision-making about future actions. If the key were retroactively applied, each member state would not only have to consider future benefits and costs but also the effects of future actions on past repayments.
- *Administrative cost burden.* Retroactive application of the key significantly increases the administrative cost burden for the development program. The Council of Ministers' report from its meeting in Bamako, dated July 17 1987, suggests the basic approach for calculations of compensatory payments. Clearly, any penalties assessed against a country in arrears to donors should not be reallocated. However, any large compensatory payment between member states probably would have to be amortized in accordance with an interstate agreement. The interest rates in this agreement could be derived from the interest rates of the loans in question. Changes in the terms of loans (such as forgiven interest and/or principal) would have to be included in the agreement that governs the compensatory payments. This agreement should

be binding over the entire program to assure as much program stability as possible. Negotiations could prove difficult and lengthy. Additionally, a significant administrative burden would be incurred due to the collection and processing of the data needed for retroactive application of the key.

- *Non-acceptability to donors.* While the concept of changing the key has been accepted by some donors in the past, no donor has accepted retroactive application of a "new" key. The OMVS document No. ER/CM/88-2 and the accompanying notes discuss this issue. Apparently the donors consider retroactive application of the key to be undesirable from the standpoint of project stability, securing repayment of the loans, and the standard practices applied in capital markets.

4. Impacts of Retroactivity on Basin Development.

Assuming that the member states are risk averse (and many government policies suggest this fact), there would be incentives to reduce investments in Senegal River Basin project development in favor of investments with less uncertainty. Further, if part or all of this uncertainty is passed to individual service users either by increasing tariffs or by limiting development within a particular service sector, incentives to participate could be reduced. Development of each member state's resources along the Senegal River, and within the Senegal River program, could be threatened and/or significantly delayed.

It is possible that repayment obligations resulting from a retroactive application of the key could have a greater impact upon the services which produce larger revenues than the services which generate smaller revenues. If greater tariffs are placed on services which were able to generate large revenues, the distribution of uncertainties could be altered, perhaps causing economic inefficiencies.

Each member state could attempt to reduce its vulnerability to the unforseen costs associated with retroactive application of the key. If a country developed more quickly than projected, that country would be likely to have to make compensatory payments in addition to its expected loan obligations. Thus, it might appear that by slowing development, a

member state could reduce its share of loan repayment (assuming other states met the projected development rates). Some incentive to slow down development already exists in the program, but it would be greatly increased under retroactivity.

If, for example, each member state reduced its rate of development in order to shift the repayment burden to other member states, revenues to all countries would fall (relative to projected revenues) while the total loan repayment burden would remain unchanged, or perhaps even increase. Increased amounts of general funds would then be needed to meet loan obligations. The result could be economic instability as well as economic inefficiency.

Not only could economic efficiency be reduced by retroactive application of the key, equity among member states could also be reduced. While the payment of loans based on actual benefits received is equitable, repayment burdens relative to benefits might be purposefully shifted either by governmental mandate or by planned changes in development rates.

5. Basis for the Non-necessity of Retroactivity.

Following the agreement among the member states establishing the OMVS (Conventions Relative aux Modalites de Financement des Ouvrages Commun) dealing with the implementation of the OMVS program, there is no necessity for retroactively applying the key. It is only necessary to substitute the term "State Borrower" for "State Co-quarantor." This reformulation is related to the fact that the member states have become debtors in order to finance repayment of the loans to OMVS not met by project revenues, and, therefore, can be considered as creditors of OMVS to the extent of their loan payments. These "credits" will accumulate with an agreed-upon interest charge, for each member state, and they will be reimbursed, according to the Conventions, by OMVS when revenues are sufficient. Thus, changes in the key and the associated repayments made by member states will be reflected in the total accumulated repayment obligation for each member state. It is suggested, however, that the Council of Ministers consider a study regarding the most equitable method to determine the way in which member states will share in the profits from the program after all debts are repaid.

Conclusions

Feasibility studies by definition, are based on expectations, forecasts, and projections. Furthermore, the recalculation of the key is performed on a mixed data that contains accurate historical data from start-up to the date of the recalculation plus forecasts and projections for the remainder of the planning horizon. The shorter the time period of the forecasts, the more accurate the projections may be, but the accuracy of calculations which involve long spans of time in the future is unknown. All keys, current and previous, are based on the best information available at the time of their calculation, including projected data. During most of the project life, projected benefits will have to play a significant role in the calculation of the key. However, history is not bound by the amount of information available to us, and much of the time this residual "unknown" has the most influence on the key.

The conclusion reached from these considerations is that the key should not be applied retroactively. History is history and no current decision can change what happened in the past. The key is a management decision tool and concerns only the future. There also exist practical considerations which militate against retroactivity. There will be extra time and effort, and the associated total cost, expended each time the key is recalculated to determine the effects of the new key on past periods. To apply the new key to the future is a costly exercise, but to apply it retroactivity presents problems in both equity among member states and extra costs of application. These conclusions are consistent with the study undertaken by the OMVS High Commission at the request of the Council of Ministers. Finally, in view of the Conventions described above, there appears to be no need for retroactively applying the key, since all payments made by each member state over the time horizon will be reimbursed.

The validity of these consideration are corroborated by the donor community's reluctance to accept modifications in the key. Donors will suffer the same costs for "changing over" from one key to the next as OMVS. However, should inequities occur in

the system, the OMVS and its member states should be able to convince the donor community that changes in the key are necessary, and the costs incurred, justified, provided that the donor community should also participate in determining the thresholds on which the key should be recalculated.

APPENDIX I - THEORY OF COST ALLOCATION

The Process of Cost Allocation

The program of the OMVS, consisting of the common works (joint facilities) and other infrastructure will provide the member states with three services (water, energy and navigation). Each service will be used by one or more economic sectors. These services are expected to yield returns which are used to repay the costs incurred in the construction, operation and maintenance of these joint facilities.

The process of distributing these costs among service users operating in the economic sectors of participating countries is called cost allocation.

The two objectives of cost allocation are first, to provide for the repayment of the costs of the common works, and, second, to promote economically efficient utilization of the services provided.

It should be noted that a benefit/cost analysis is "global" in that it concerns the total benefits compared to total costs of the project. Cost allocation allows these costs to be divided among services and countries based on their "individual" benefits. However, it must be clearly understood that cost allocation is not a method for setting actual prices for project services. Only in circumstances in which free markets exist for the services will cost allocation and pricing of services be the same. For cases, such as the Senegal River Basin Program, where each country establishes income redistribution policies, taxes and subsidies, and fixed prices for some or all commodities, financial conditions may differ substantially for users of project services. The project benefits are re-distributed. Cost allocation considers all benefits to a service or country, no matter to whom they may accrue.

The very need to allocate costs implies that it is impossible to attribute them precisely to the sectors where benefits are expected or directly to countries. Increments to the services do not entail increment to the costs of joint facilities. That is, the sum of the costs associated

directly with each service does not equal the total project cost. Each service must bear some share of the joint costs.

The cost allocation process involves two main stages, depicted in Figure 1:

- *Allocation of project costs to the services* which the project generates using an appropriate methodology that distributes costs based on benefits derived from each service.
- *Allocation of responsibility for payment of those service costs to member countries*

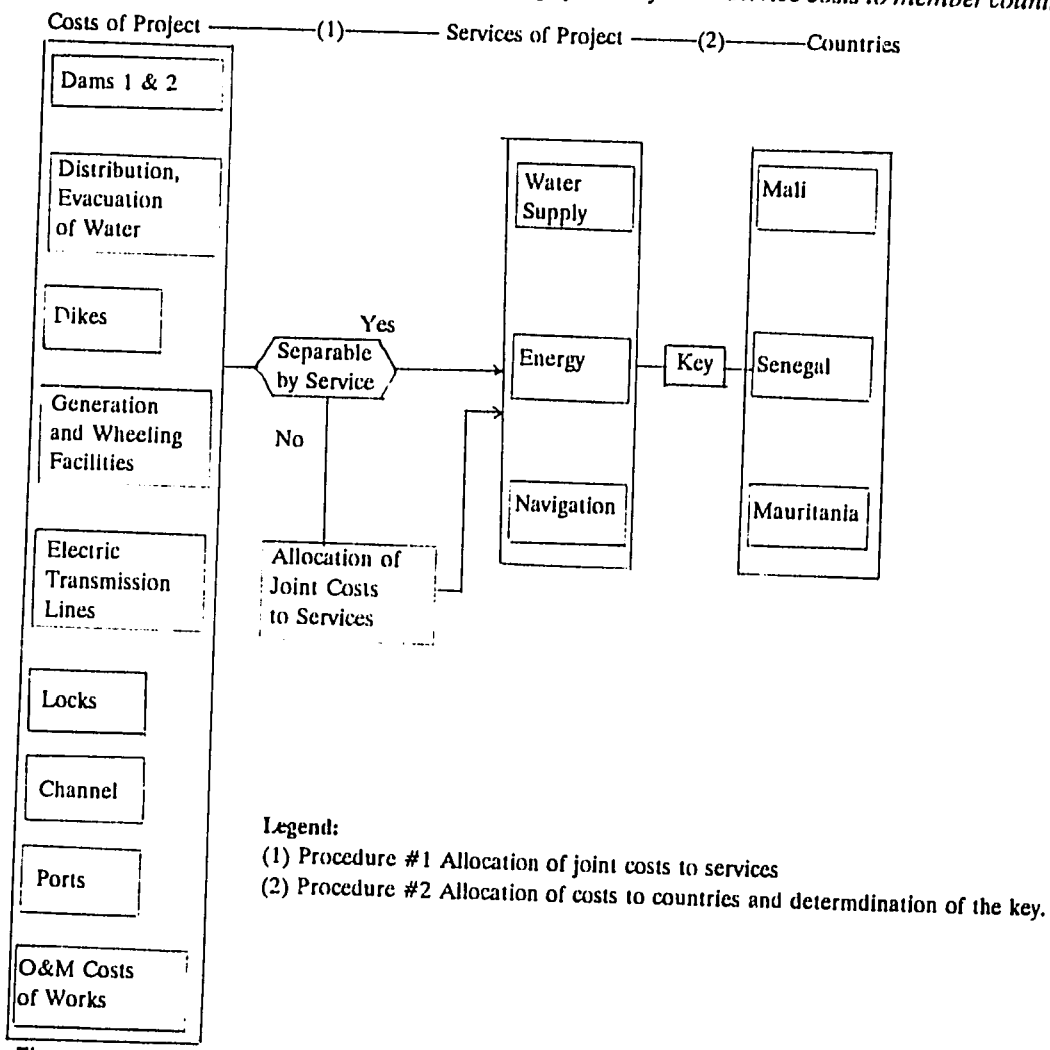

Figure 1: Diagram of the cost allocation process

While this process appears to be simple, it is in reality complex. The major difficulty lies in assuring that the allocation of costs not directly associated with a specific service is equitable. The problem of allocating these "joint costs" is a problem for which theoretical solutions do not exist, and practical solutions must be chosen.

In the case of the OMVS, the problem is complicated by the fact that some users of project services may not be able, in reality, to pay for those services, as a result of policies and income redistribution programs within the separate countries as well as the nature of public goods. The responsibility for reimbursement of the debt is assigned to member states, as the sovereign entities in the program. The system of allocation must reflect both economic efficiency and equity among the services and states.

The questions of economic efficiency and equity are the bases for selection of a workable methodology which allows each state to profit from the project and determines the responsibility for repayment of the debt on an equitable basis. This Appendix presents the theoretical bases for selection of such a methodology.

Definition of Costs

In order to economically justify a project, it is necessary to estimate the costs and benefits of that project. However, once the benefits are found to exceed the costs, then the repayment responsibility for project costs, termed "cost allocation," must be determined.

Before examining the criteria for the allocation or project costs, it is necessary to have an understanding of the various categories of project costs and the way in which those costs are calculated. First, there are direct and indirect project costs.

Direct costs are those costs which can be identified directly with the project conceptualization, planning, development and management. For the purpose of this report, direct project costs include: 1) planning and installation costs; 2) project operation, maintenance, and replacement costs; and 3) interest costs.

There are other project costs which are more indirectly related to the project itself. Exploitation of the Senegal River for agricultural and industrial purposes may change the river's flows, alter its navigability, and change its water quality which may affect public health and ecological stability. These side impacts must be translated in terms of costs and included in the costs to be allocated. Costs which could be considered for this purpose are:

- Costs of direct external project diseconomics, such as increased incidence of water-borne diseases or the loss of access for nomadic herders;
- Costs of indirect external project diseconomies, such as the incremental cost of housing or the social costs of changes in cultural traditions.

Cost Categories Involved in the allocation process

Cost categories are systematic distinctions among project costs. These project costs are classified into four categories, as indicated in Figure 2: specific costs, imputed costs, separable costs or joint costs.

1. *Specific costs:* are the costs of those physical facilities (inputs) which are required exclusively by a particular identifiable service (for example, canals with irrigation or turbines and transmission lines with hydroelectricity). All costs associated with Diama Dam are specific costs since they are assigned to water supply.
2. *Imputed Costs:* Costs of the common works which can be allocated to specific services or countries based on a "with"-"without" cost comparison for each service.
3. *Separable costs:* The separable costs are the specific costs plus any portion of the cost of the joint inputs (such as a dam) which can be legitimately allocated to a specific service (imputed costs) [(1) + (2)].

4. *Joint costs:* are the costs of the joint inputs which cannot be assigned to any specific service. These are the remaining costs when separable costs are subtracted from total project costs.

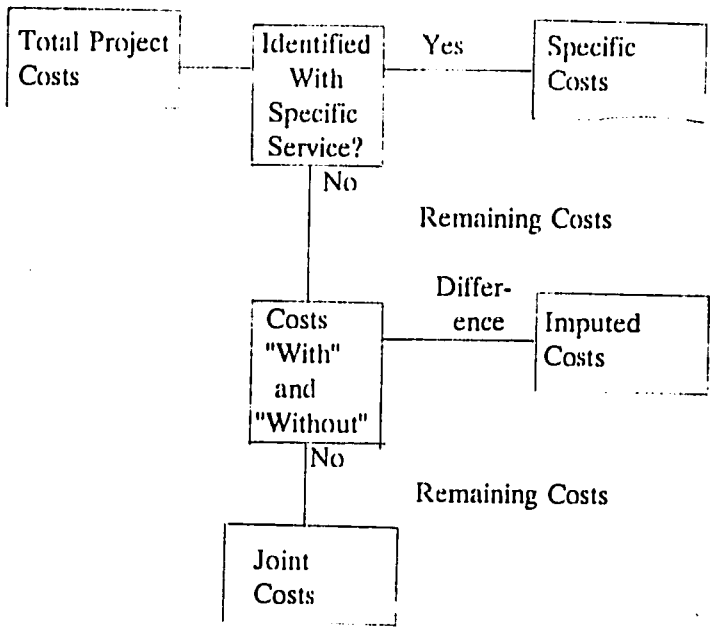

Figure 2 . Calculation of Specific, Separable, and Joint Costs.

In the logical procedure of cost allocation, cost categories are broken down by service and by country:

- Costs which are separable by project service and by country.
- Costs which are separable by service but which are not separable by country.
- Costs which are not separable by service but which are separable by country (unlikely to occur).
- Costs which are not separable by service or country (joint costs).

There are two other types of costs which are necessary for some of the cost allocation procedures described in Appendix II. These are:

5. *Alternative costs:* The costs of the least-cost single-purpose project which will provide the same service.
6. *Justifiable costs:* The lessor of the benefits generated by the service or in the country and the alternative costs for that service and/or country.

Definition and categorization of the OMVS program costs

The types of costs of the OMVS project for each category described above are listed below:

Specific costs

Costs which could be considered as specific to the provision of water include:

- Costs of development of new acreage for irrigation
- Costs relative to pumping or other delivery systems
- Costs of operation and maintenance of those facilities.

Note that these costs have not been used as specific project costs in the past because the development of irrigation has been considered a prerogative of each country, and not a part of the common works.

Costs which may be specific to the provision of energy include:

For the production of energy:

- Production facilities
- Turbines and connection equipment
- Generators
- Transmission lines
- Transformer stations
- Telecommunications
- Supervision and inspections of works
- Penstocks

For operation and maintenance:

- O&M for the engineering works
- O&M for equipment
- Renovation of equipment

Costs which may be specific to the provision of navigation include:

- Ports
  - River-maritime Port at St. Louis
  - Equipment
  - Port at Kayes
  - Intermediate ports (Rosso, Richard Toll, Dagana, Podor, Boghe, Kaedi, Matam, Bakel, Gouraye, Ambidedi)
- Channelization
  - Channel maintenance
  - Equipment
  - Buildings and repair installations
- Floating stock
  - Barges
  - Repair of floating stock
- O & M of the navigation system

Imputed costs

For the Senegal River Program, Manatali Dam is the principle common works. Its costs can be imputed to services using the following information:

A dam height of 213 meters is necessary to provide adequate water (WS) for irrigation of 255,000 hectares, navigation requirements of flows (N) of 100 m^3, and adequate head for the production of 800 gigawatt-hours of energy (E) under all possible drought

conditions. However, an analysis of the costs of water deficits indicated that a dam of 208 meters was the most economical configuration possible.

A dam of 192 meters would be sufficient to provide the needs for irrigation water and navigation combined, a dam of 189 meters would assure the minimum water for irrigation, and a dam of 186 meters would assure adequate flows for navigation.

Costs of Manantali can be imputed as follows:

- Costs imputable to energy:

  $Costs_E = Costs_{(E+WS+N)}$ [208 m] - $Costs_{(W+N)}$ [192 m]

  Note that the dam height necessary to provide 800 Gwh is 208 meters, so that both other services can be provided by a dam constructed only for energy.

- Costs imputable to water supply:

  $Costs_{WS} = Costs_{(WS+N)}$ [192 m] - $Costs_{(N)}$ [186 m].

- Costs imputable to navigation:

  $Costs_N = Costs_{(WS+N)}$ [192 m] - $Costs_{(WS)}$ [189 m].

In fact, the height of the dam cannot be reduced for providing energy and navigation or water supply. In traditional cost allocation methods, no imputed costs would be assigned to water supply or navigation, and the cost of a 192 meter dam would be considered as totally common costs. However, it is reasonable to take account of the interdependence of the two latter services. For this reason, the Council of Ministers, at its meeting in Nouakchott in March, 1981, chose to adopt the above-described procedure for identifying imputable costs.

Diama dam was constructed to assure the water supply, although the dam needed to include locks for navigation as a result of the occlusion of the river. Since the provision of water flows from Manantali is sufficient to provide for navigation, and because the Diama dam did not provide added navigational services, the cost imputable to Diama for navigation is zero.

Criteria for Cost Allocation

As indicated above, cost allocation is based on a set of criteria which arise from the two fundamental objectives of economic efficiency and equity. Because these concepts are not universally understood, it is necessary to provide a formulation which is as clear and useful as possible. This will be accomplished in three steps:

(1) The criteria will be defined.

(2) General principles of the application of these criteria will be formulated.

(3) These principles will be translated into precise rules.

1. Definition of economic efficiency and equity

Economic Efficiency: Economic efficiency concerns the pricing of services such that optimal utilization of resources occurs (maximized benefits to the project subject to the various constraints imposed by the environment and the project). In general, economic efficiency requires that the benefit derived from the last unit of a service (marginal benefit) be equal to the cost required to produce it (marginal cost). This equality establishes an "optimal price" at equilibrium.

Economic efficiency is rigorously defined in neo-classic theory. In a theoretical sense, economic efficiency is a combination of technical efficiency and allocation efficiency. Technical efficiency refers to the utilization of resources in such a way as to maximize the output from a given set of resources (that is, production is maximized for a given combination of inputs). Allocative efficiency refers to the equality of the value of the marginal product of each resource to its marginal cost.

In most publicly developed projects, the marginal costs of production of each of the services do not include the fixed (or joint) costs of the project. The equation of the price of a service with its marginal cost fails to produce adequate revenues to pay for all the project costs (specifically the joint costs are not "covered"). Consequently, the typical approach to economic efficiency has been a global one (aggregate economic efficiency) in which the total benefits are compared to the total costs. Cost allocation, which is formulated

to deal with the joint cost problem, is as a result, usually based on global (aggregate) analysis.

Equity: Equity, the other objective of cost allocation, results from objectives other than economic efficiency, and arises in part from the failure of marginal pricing to meet all project costs. Equity must be defined in such a way as to make both the reimbursement of costs possible and to assure that participants in the project do not lose their incentives to participate.

This concept is less precise and more difficult to define, because it has two aspects: horizontal equity (those in similar situations are treated the same) and vertical equity (defined relative to the treatment of rich and poor based on social criteria).

More precisely, cost allocation is equitable if it permits at least a sharing among all users of the economies realized from the multiple purpose project compared to single purpose projects. The net benefits (after project repayment) for a given user or country must be at least equal to the net benefits which could be realized from an alternative single-purpose project. Each user should realize a comparative advantage from the multiple purpose project, and no user or country should subsidize another.

The sub-committee on benefits and costs for the Federal Interagency River Basin Committee put the accent on the notion of "just" division of costs in the following terms: "the objective of all allocation of costs is to equitably allocate the costs of a project among the different users of its services based on a proportional sharing of the economies resulting from a multiple purpose project. (Federal Interagency River Basin Committee, 1950). Circular A-47 of the Bureau of the Budget issued in 1952 (the "Green Book"), indicated the same conditions.

Other criteria: Selection of a method to be used for the allocation of joint costs also depends on a number of other considerations. Among these are simplicity, flexibility to changing situations, and acceptability to all participants.

2. General Principles

A successful cost allocation procedure should meet the four following criteria:

- It should ensure that adequate performance incentives are provided for all project participants.
- It should be equitable among economic sectors and the participating countries. No country, economic sector, business, or person should be made worse off by having the project developed and by being assessed a portion of the repayment responsibility.
- The cost allocation method and repayment scheme should provide for efficient use of the capital and other resources required by the project. No penalties should exist for the most efficient use of project services.
- The sum of all allocated costs should equal total project costs.

3. Specific Criteria

- Each service or country should equitably contribute to the realization of economies resulting from the project. No service or country should be assigned costs in excess of the benefits which it derives from using the project services. However, no service or country should subsidize another service or country.
- The minimum costs allocated to a service or country must be the separable costs associated with that service and/or country. All specific costs of a service should be assigned to that service. All specific costs associated with a service in a given country should be assigned to that country.
- The maximum cost allocated to a service or country should not exceed the justifiable costs to that service or country. That is, no service or country should be assigned costs exceeding the minimum of benefits or the costs of providing the service by the least-cost single-purpose project.
- The total allocated costs must be equal to total project costs.

These criteria will be used to examine each of the possible methods for allocating costs described in Appendix II, which follows. However, the criteria require that estimations of benefits generated by the project be determined.

Definition and Estimation of Benefits

Estimating project benefits is an important part of the cost allocation analysis. Benefits accrue to the use of the project services to economic sectors and to countries. Benefits can arise from both the increasing value of production associated with the project, or from the reduction of costs of obtaining the project services. However, the form of benefit measures is not always evident and the problems of estimation can be complex.

Various methods for calculating project benefits for the OMVS have been discussed in earlier publications (Report 1 Utah State University, 1976 or the RONCO report RONCO, 1987). Seven methods have been identified below. Methods 1 through 4 deal with the direct or primary benefits. They do not include the effects of development on other sectors or industries in the economy. Secondary (indirect) benefits are considered in Methods 5 and 6 by accounting for linkages with others sectors of the economy.

Method 1 - Benefits are Proportional to Use. This method assumes that benefits are directly proportional to the degree to which facilities are used by the various economic sectors. This method of estimation of benefits was used in the Boeing Report (Riley, 1974).

Method 2 - Benefits Equal Sale Value of Services. This method assumes that each service can be sold on the free market, and that the gross revenues from the sales of the services are equal to the benefits. This method can only be used if the prices of services are fully market-determined rather than administered. While some services may have markets (such as electricity), others may not (irrigation water or navigation services). Even if markets exist, prices may favor one sector relative to another, either accidentally or as a planned procedure for subsidization.

Method 3 - Benefits Equal Alternative Costs. This procedure does not use direct sales as a means of calculating benefits. Benefits are determined by the next least costly method of producing the services. The benefits are assumed to be the cost which would have been experienced if the next best alternative were used. For example, petroleum-fired thermal plants might be the next best alternative to hydroelectricity. The cost of thermal electricity

would be used as a measure of the benefits to hydroelectricity. This method is somewhat similar to a shadow price estimation of value.

Method 4 - Benefits are the Returns to Users of Project Services. This method estimates the total value of the services from the revenues to users of these services. Three alternative measures of returns have been suggested or used in water projects in the US. Three general variations of this method have been used:

gross primary revenues, net primary revenues, and net primary benefits.

(1) *Gross primary revenues* are the total revenues generated by a user of project services. The costs of these services, and the costs of all other inputs, including capital, amortization, and labor, are included in the value at which the final products are sold. This measure is one approach to estimating the increase in gross national product which directly results from the use of services.

Three problems arise from this approach:

First, retained production (utilization of production for intermediate goods, such as seed sources, or home consumption) does not have a market price, and it is usually a significant part of a water project in developing countries. There are two possible solutions to this problem:

- Use of a shadow value based on the cost of provision of the production by alternative means (such as importation of agricultural goods). This approach is viable only in the cases where the price is independent of the supply and demand for the commodity in the country. If the price is fixed below a market price, the price on black markets could be used, although that price is elevated by the amount of risk involved.
- Use of actual prices in the market. This approach is viable only if a free market exists or if the supply and demand can be accurately estimated from existing data. World prices can also be used, net of transport cost (for exported goods) or port price plus transport costs (for imported goods). The choice of approach depends upon the available data and the conditions found in the local markets.

Second, benefits are double-counted, since the loss of capital value resulting from the production of goods and services (capital replacement allowance) and the output which causes depreciation are counted in the value of the service. If no accurate measure of depreciation is available, the adjustment will be arbitrary.

Finally, and most importantly, gross revenue does not account for payment of the costs of inputs. The cost of inputs other than project services must be subtracted from gross benefits to obtain the amount of benefits that accrue to the project services only.

(2) *Net primary revenues* are calculated by subtracting the costs of production from gross primary revenues. This method generates the "profits" to each sector resulting from the project services. It may not be necessary to know the budget of each user to determine net returns. The demand curves for project services (if known) represent marginal profits (Method 2).

If the cost of agricultural labor is part of the costs of production, net primary revenues will include any payment to labor in excess of its opportunity cost, which to some degree reflect value added (Method 5).

(3) *Net primary benefits* are calculated by subtracting the profits to existing production from net primary revenues which will be lost when the project is developed. The resulting value is the increase in benefits due to the project service. This measure is equivalent to net primary revenues if no existing production is foregone. Failure to deduct existing profits leads to an overstatement of benefits. For example, if water were provided to increase the production in existing rice fields, the net benefit to the project would be the increase in profits to rice production.

If, for a given sector, there is no previous production which will be abandoned, the method is the same as the net primary returns.

Method 5 - Benefits Equal Value Added. Value added includes the net primary returns to the sector plus the payments to labor, management, and entrepreneurs. From a theoretical standpoint, value added is the increment of the net national output resulting from

the project. The net national output is calculated by the value of final sales for the period (normally a year). The net profit (payments to fixed inputs of production) plus payments to households for the value of labor is equal to the sale value of the final products. Thus, the sum of increments in net profits and increments in wages is equivalent to increment in net national product attributable to the project.

Value added tends to overestimate the benefits of a project if the payments to inputs results from transfers of inputs (principally labor) from other uses. In such a case, there is little or no gain in benefits. Only if resources are un- or under-employed do payments to labor represent added benefits.

Method 6 - Benefits Equal Value Added Plus Secondary Benefits. Secondary benefits are benefits induced by and stemming from increases in economic activity in use sectors. "Induced by" refers to industries which provide inputs to the use sectors (backward linkages). "Stemming from" refers to those industries which process added outputs from the use sectors (forward linkages). The further removed an industry is from the use sectors, the more difficult it is to estimate the increases in economic activity which result from the project, and the smaller the impact is likely to be.

Secondary benefits are usually estimated by economic multipliers, which relate a change in one sector's production to the change in the production in all of the sectors. These multipliers are usually obtained from econometric or input/output models. Econometric models usually involve a statistical estimate of the relationship between basic industries and other industries in the economy. Input/output models are detailed mathematical models of all of the sectors in an economy.

The estimation of secondary benefits is a difficult task. It requires considerable information regarding the structure of the economy under consideration and a detailed knowledge of the resource markets. Use of multipliers requires that precise data regarding the structure of costs and benefits of each sector be known, and that production is infinitely elastic with respect to costs.

Payments to unemployed or underemployed resources are the true measures of secondary benefits. The linked sectors must increase total aggregate economic profits and/or other income to households to generate secondary benefits. Payments to already fully employed resources are not considered secondary benefits.

Arguments for the participation of the central government in project development are based on the existence of secondary benefits since it is impossible to made secondary beneficiaries pay directly for project services.

External benefits may also result from a project (for example, import substitution and positive effects on the balance of payments). These are also a basis for government support of projects.

The selection of the particular benefit method for the use in cost allocation procedures depends on two important considerations: 1) the needs and preferences of those involved in the cost allocation, and 2) the availability of data. Data requirements increase as the methods become more sophisticated. Some methods, such as demand estimation, may require data which are somewhat less complicated but none-the-less more difficult to obtain. A review of the data available and the requirements of the allocation problem should be made periodically. Table 2 lists the various methods of calculating benefits.

Table 2: Method of Calculation of Benefits

Methods	Method 1	Method 2	Method 3
Services	Direct Output of Project	Value of the Direct Output	Comparative Costs
Water	Water storage or (Utilization of water)	Unit price multiplied by the amount of water sold	Cost of water by the least cost alternative project for a single-purpose water project
Energy	Energy produced	Price multiplied by Kwh sold	Cost of energy by the second best alternative project (thermal energy)
Navigation	Releases for regularization of the river	Price multiplied by ton-kilometer of freight	Costs of transport compared to the next best alternative (road or rail)

Methods	Method 4.1	Method 4.2	Method 4.3
Services	Primary revenues	Net primary revenues	Net primary benefits
Water	Value of agricultural products sold on the market times the quantity produced including home consumption	Primary revenues less costs of production (including capital)	Net primary revenues less the value of foregone production (e.g., the value of production of flood or rainfed agriculture replaced
Energy	Price of industrial (minerals, etc.) times the quantity sold	Primary revenues less the costs of production (including capital)	Net primary revenues less the value of production foregone
Navigation	Price of transport times the quantity of goods transported	Primary revenues less the costs of production (including capital)	Net primary revenues less value of foregone production (if any exist)

Methods	Method 5	Method 6
Services	Value Added (VA)	Value added plus secondary benefits
Water	Net primary revenue plus salaries and profits paid	VA + VA of other sectors from multipliers
Energy	Primary net revenue plus salaries and profits paid	VA + VA in other sectors from multipliers
Navigation	Primary net revenue plus salaries and profits paid	VA + VA in other sectors from multipliers

Economic Versus Financial Data

Cost allocation is based on economic analysis. The assignment of the responsibility for project costs should be based on aggregate economic (as opposed to financial) benefits generated.

Economic measures relate to a standard set of conditions which apply to all countries in question. Economic values are defined as opportunity costs, which are the values of the inputs or outputs in their next best alternative uses.

Financial measures are prices and costs which exist in a given country or region at a given time. These measures include all the effects of government intervention, such as taxes and subsidies. However, as indicated above, cost allocation deals with total benefits resulting from a project, to whomever they accrue.

In neoclassical economic theory, the prices which result from a free market reflect opportunity costs. However, if prices are administered (either explicitly set or restricted by some government entity), the existing price may not reflect the opportunity cost.

Opportunity costs are monetary measures of the real value of inputs or commodities in a market. When goods are supplied to the world market, a world price less transportation costs ("farm gate" price) is the local economic value to be used. If goods are consumed from the world market, the local economic value is the world price plus transportation charges.

When no world market exists for a particular resource or commodity, the economic value is more difficult to obtain. Existing local market prices may represent an appropriate measure of opportunity costs. However, any intervention in these markets, such as taxes, subsidies, price fixing, or other government policies, cause distortions. In these cases (which are the most common), local prices do not reflect opportunity cost. They are financial values.

The world market price of close substitutes for non traded commodities may reflect their economic value. There are also publications available from the International Monetary Fund (IMF) and other agencies which report "shadow values" (estimated world prices) for various commodities and services. However, it may be necessary to develop these opportunity costs, or shadow values, for some commodities or services.

For example, wages paid for skilled labor in a project may represent a world market price because skilled labor is in short supply throughout the world. So long as labor is mobile, world markets will set the equilibrium wage rate (opportunity cost). However, unskilled labor is generally relatively plentiful during certain times of the year, even in highly developed economies. The opportunity cost of unskilled labor depends on employment patterns and wages. Gittinger (1982) recommends the use of the opportunity cost of unskilled labor in agriculture as the appropriate measure of unskilled labor's opportunity cost. In most instances unskilled agricultural labor is fully employed only for a part of the year (usually harvest and/or planting seasons). Its opportunity cost would be the total wages paid for the period(s) during which this labor was in short supply. An alternative is to use a measure of world price of unskilled labor from other sources, adjusted for local conditions (such as estimated in RONCO [1987] for the Gambia River Basin).

Another adjustment is needed when the local currency is under or overvalued. This occurs when the local currency is exchanged at an official rate which is different from its world market rate. For example, the FCFA trades for French francs at fixed rate of 50 to 1. The world currency market might not set this rate. On the other hand, if all values used in the cost allocation are in a currency which freely floats in the currency market, some of the currency valuation problems are avoided. The market exchange rate of the French franc relative to the U.S. dollar will include consideration of the exchange rate between the French franc and FCFA. Data on the value of local currency are available from the IMF, local central banks, and other sources.

Finally, all economic costs and benefits occur over a time horizon. Both costs and benefits are generated throughout the life of the project in varying increments. For economic analysis, all costs and benefits to be comparable must be discounted to a base year. The choice of a discount rate is very important, since the rate effects the value given to future benefits and costs. The economic discount rate is the opportunity cost of the capital which is committed to the project.

APPENDIX II- APPROACHES TO COST ALLOCATION

There are two families of methods for cost allocation: allocation based on physical use and allocation based on economic measures of benefits and costs. Under each general type of allocation approach, there are several sub-categories, as follows:

Physical Methods

- Equally among services or countries
- Proportionally to the rate of utilization of either physical structures (storage) vs use of services
- By decreasing priority within limits of benefits.

Economic Methods

- Total (aggregate) benefit methods
  1. Proportional to the excess of benefits over separable costs (net benefits)
  2. Separable cost-remaining benefits (SCRB)
  3. Adjusted separable cost-remaining benefits (ASCRB)
- Marginal benefit methods
  1. Inverse elasticity pricing
  2. Full optimization
- Average benefit method

Each of these methods is discussed below, and evaluated using the criteria developed in Appendix I.

Physical Methods

These methods do not consider benefits received by users of project services, and, therefore, may be economically inefficient and/or inequitable (that is, allocated costs may exceed benefits).

Allocate equally among services or use sectors. In this method, each service, sector, or country bears an equal share of project joint costs. The benefits are not considered; therefore, it does not meet the efficiency or equity criteria.

Allocate proportionally to the use of facilities or quantity of use. Under this method benefits are assumed to be directly proportional to the use of facilities. Cost allocations, therefore, are made in direct proportion to the degree to which facilities are used by the various services or countries. Only if benefits are the same for all units of all services and countries would this method meet the efficiency criteria. This is seldom the case. Storage for irrigation (a relatively low-valued use) may be greater than the storage required for other uses (such as a high-valued municipal or industrial water). Thus, the charge for irrigation water could be greater than the contribution of that water to the benefit of the project.

Allocate entirely to the highest priority service or sector, within the limit of the benefit received, then to the next highest priority service. This method may be inefficient and inequitable because priorities may not be assigned by benefits. A service or country which may require considerable use of facilities or which may be designated as the highest priority may not be the service or country generating the greatest benefit. Further, the assignment of priorities could be very arbitrary.

Economic Methods

Economic methods are comprised of total benefit, marginal benefit, and average benefit approaches.

Total benefit methods

Three methods can be identified in this category: benefits in excess of separable costs (net benefit method), remaining benefit (SCRB method), and adjusted remaining benefit (ASCRB method).

Allocate proportionally to the excess of benefits over assigned separable costs. In this method, the portion of joint costs assigned is calculated by dividing the net benefits for that service or country by total net project benefits. "Net" is defined as benefits derived from the service or country minus the separable costs.

While this approach is based on benefits, it does not account for the possibility that alternative means of supplying the service at a lesser cost could be available. Costs could be assigned which are greater than providing the service by other means (failure to meet criteria 3). In that case, there would be no incentive for users of that service to participate in the project.

This method could be easily programmed on PC's and requires a minimum of data.

Allocate proportionally to the remaining benefits. Subtracting the separable costs from the justifiable cost gives the remaining benefits.Justifiable costs are the lesser of the benefits to a service or the cost of the least-cost single-service alternative. There are two variants of this method: *the alternative justifiable expenditure method* and *the separable cost remaining benefit method (SCRB).* In the former method, specific costs are costs subtracted from justifiable costs. In the latter method, the separable costs are subtracted from justifiable costs. Clearly, the use of separable costs is more equitable.

The SCRB method is completed in four steps. Figure 3 is a flow diagram of the SCRB method, as well as the ASCRB method, described below.

Calculation of the Separable Cost Remaining Benefit Method

Justifiable costs for each country are the lesser of benefits or the costs of the least-cost single-service alternative (*Step 1*).

Separable costs for each service or country would be subtracted from the justifiable costs (*Step 2*). The result would be the remaining benefit to each country or each service. The separable cost to countries will most likely be composed of only specific costs. A

"with/without" analysis of separable portions of the joint service facilities is likely to be difficult and arbitrary.

The ratio of remaining benefits a service or country to the total remaining benefits for all services or countries would be used to allocate the service costs (*Step 3*).

The ratio of total allocated costs for a given service or country to total allocated costs would be calculated (*Step 4*) and indicated in the "key."

The SCRB method meets the economic efficiency criteria and would be easy to program on PC's. The data requirement would be minimal, and current data sources should be adequate. However, a problem with equity arises with this method, since the cost savings afforded to other services or countries are not taken into account. A means of adjusting for these cost savings is required.

Adjusted Separable Cost Remaining Benefit Method

In 1977, Loughlin (1977) proposed such an adjustment to the SCRB. This method is called *the Adjusted Separable Cost Remaining Benefit method (ASCRB)*. The rationale for this method is that it adjusts separable costs to reflect the assignment of a portion of project savings from multiple-purpose projects (as compared to single-purpose projects) to the separable costs. This method adjusts for the inequity in the SCRB formula by a applying a credit to the separable costs to account for project savings. As a result of this adjustment, each service or country is assigned a more reasonable proportional share of savings resulting from multipurpose development.

The separable cost of each service or country is multiplied by the adjustment factor, which reduces the remaining benefits and changes the ratio of remaining benefits. Those services which provide more cost savings have a smaller proportion of joint cost allocated to them. Total allocated cost, however, remains the sum of unadjusted separable costs and allocated joint cost.

The ASCRB method is implemented in five steps.

Calculation of the ASCRB Method

(*Step 1*) is identical to the SCRB method. For a given service or a given country, the justifiable costs to other services or countries would be the lesser of the total service costs minus the separable costs, or the sum of justifiable costs to other services or countries.

The adjustment factor is calculated by dividing the sum of justifiable costs to the service or country in question plus lesser of the sum of the justifiable cost to other services or countries, or the total project costs minus the separable costs of the service in question, by the total service cost. The separable costs are then multiplied by the adjustment factor. These "adjusted" separable costs would then be subtracted from the justifiable costs to obtain the remaining benefits (*Step 2*).

The next steps to calculation of the allocated costs would be the same as in the SCRB method (*Steps 3 and 4*). The "key" would show the portion of total repayment responsibility for each service or country.

The ASCRB method makes the allocation of costs somewhat more equitable. The method meets the four criteria. As with the SCRB method, ASCRB is based on total, not marginal, benefits. It is easily programmed and would use the same data base as the SCRB method. An example is presented in Annex IV.

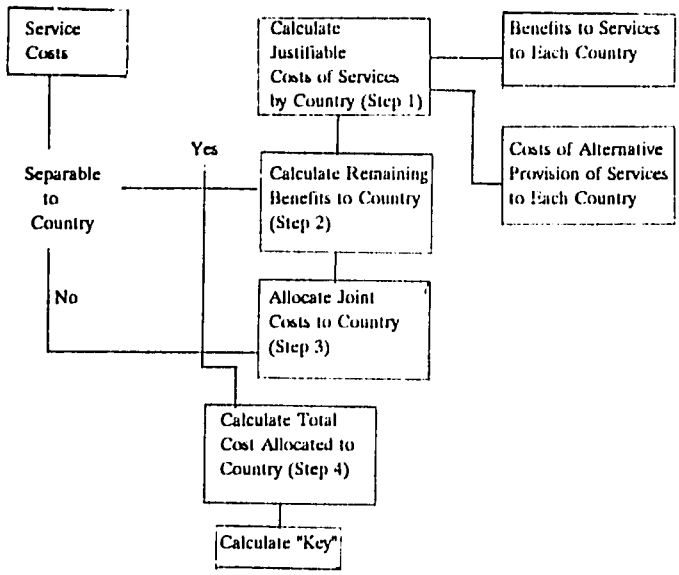

Figure 3. Allocation to Countries by ASCRB or SCRB

Marginal Benefit Methods

Marginal benefit methods use an approach which is based on maximizing the present value of the social net benefit derived from the project and its services. This social net benefit is generally conceived to be a measure of utility or satisfaction. However, the exact form of utility functions are, in general, unknown or impossible to determine. The measures most frequently used are the sum of consumers plus producers surplus measures, which are derived from the demand curves for a service (representing the willingness-to-pay for that service) and the supply curve for that service (representing the marginal cost of producing the service). Mathematically defined:

- Q_{ij} is the quantity of service j consumed in country i
- $P_{ij}(Q_{ij})$ is the price of the service j consumed in country i as a function of the quantity (known as the inverse demand curve)

where i indexes countries, and j indexes the services.

- $B(Q_{ij})_t$ is the benefit obtained from service i in country j in time period t..

The mathematical formulation of this method is given in the following expressions:

Maximize $\Sigma_t \; 1/(1+r)^t \;\; \Sigma_{ij} \; B(Q_{ij})_t$

subject to physical and economic constraints on the project or the system.

Two variations of the marginal benefit approach could be considered: the inverse elasticity pricing method and the full optimization method.

Allocate according to inverse elasticity "pricing" (IEP)

The inverse elasticity method is based on the condition that for projects with joint costs, equating marginal benefits and costs will not provide adequate (economic) revenues to pay for the project (declining average cost projects). Thus, maximization of social benefits must be accomplished subject to the constraint that the total cost of the project is repaid. The resulting solution generates optimal "prices" which differ from marginal cost inversely with the elasticity of demand.

Elasticity of demand is a measure of the sensitivity of consumption of the service to variations in price. Inelastic demands are relatively insensitive to price changes, while elastic demands are relatively sensitive to them. Mathematically:

$$e(ij) = \frac{dQ_{ij}}{Q_{ij}} * \frac{P(Q_{ij})}{dP(Q_{ij})}$$

The mathematical statement of inverse elasticity pricing is:

Maximize $\Sigma_t \; 1/(1+r)^t \;\; \Sigma_i \int_{Q_j} [P_{ij}(Q_{ij})\text{-Marginal Cost}_{ij}(Q_{ij})]dQ_j$

$\forall j$

Subject to:

$\Sigma_t \; 1/(1+r)^t \;\; \Sigma_i \; \Sigma_j \; P_{ij}Q_{ij} \geq$ Total Project Cost

$\Sigma_t \; 1/(1+r)^t \;\; \Sigma_i \; P_{ij}Q_{ij} \geq$ Separable Cost_j (Costs to service)

$\Sigma_t \; 1/(1+r)^t \;\; \Sigma_j \; P_{ij}Q_{ij} \geq$ Separable Cost_i (Costs to country)

$\Sigma_t \; 1/(1+r)^t \;\; \Sigma_i \; P_{ij}Q_{ij} \leq$ Justifiable Cost_j

where:

t = time period

i = country

j = service

r = discount rate

The optimal results are P_{ij}^{*}, Q_{ij}^{*} for all i, j

The country allocation is $\Sigma_j P_{ij}^{*} Q_{ij}^{*}$ for each i

The "Key" is $\Sigma_j P_{ij}^{*} Q_{ij}^{*}$ / Total Project Costs for each i

The demand functions $[p(Q_{ij})]$ are the most difficult data to obtain. The demand curves may represent either the value of the marginal product of the service as an input to a productive use (such as the marginal value of water in irrigated agriculture) or the value (demand) of final consumers (households) of the service. However, both demand and marginal cost curves for each service in each country must be known.

The optimal "prices" are established by the model such that the "price" differs from marginal cost inversely with the elasticity of demand. The more inelastic a demand curve is, the higher will be the optimal "price." The separable cost constraints must be included to ensure that no cross-subsidization occurs.

The process of using the inverse elasticity pricing method is described below and illustrated in Figure 4.

Demand curves would be developed for services in each country (*Steps 1 and 2*).There are two approaches to determining demand curves: statistical (econometric) and budget-based (optimization). The former would require data on the consumption of the services at various costs (or sales prices). The latter would require that budgets be developed for users of the services.

Once the demand curves are known or estimated, total benefits (the sum of the consumers' and producers' surpluses) would be maximized subject to the constraint that service costs must be repaid (*Step 3*). This is a nonlinear optimization problem because it requires that both prices and quantities be variable. If the data suggest that marginal costs are constant (which is likely), the consumers' surplus in all countries will be maximized (although not necessarily in a single country). An optimization program (such as LINDO or

GAMS) is used to determine the optimal "prices" and quantities of use of a given service in each country.

The method establishes optimal "prices" (opportunity costs) and use levels for the service in each country (*Step 4*). The "prices" will be higher for demand curves which are "steep"; that is, for those demand curves which indicate that quantity of the services purchased varies only a little as prices rise or fall (an "inelastic" demand). Conversely, "prices" will be lower for those demands which are "flat"; that is, for demand curves which indicate that quantity of the service purchased will rise or fall by relatively large amounts as prices fall or rise, respectively. "Elasticity" is, then, a measure of the sensitivity of quantity purchased or desired to price changes.

The total service cost allocated to a country would be the optimal "price" times the optimal quantity. The key would be generated from these allocated service costs (*Step 5*).

This method meets the criteria of economic efficiency. However, the generation of prices for a single service which varies across countries may appear to be inequitable. The cost allocation process is meant to allocate the responsibility for repayment of project costs proportionally to the benefit received. Differential pricing of project services is common among public utilities. It is often implicitly based on an IEP rule.

This approach cannot be programmed using a single menu-driven computer model. It requires combining and adapting pre-packaged mathematical optimization as well as statistical programs with an allocation model. Demand and marginal cost curves will have to be generated. Marginal cost will be estimated from project data on separable and joint costs of the project.

Users of this allocation process would have to be skilled in the use the statistical (TSP, SASS, etc.) and mathematical programming (GAMS, LINDO) packages and experienced in economic analysis, including the basic techniques of statistics, mathematics and optimization. This would probably require at least a Bachelor's degree and some experience with computer modeling. Users would have to transfer results from one step to the next. It would be necessary for them to have a good understanding of the data

management. Otherwise, examining alternative data or projections could only be accomplished with outside help.

The data requirements for the inverse elasticity approach are much more extensive than for the benefit methods. A series of farm budgets would be developed for estimating the marginal value of water in agriculture.

Navigation and energy present a more difficult problem. Users' budgets or willingness to pay are more conjectural and based on less hard data. Both energy and navigation services may used by irrigated agriculture. IEP's would be determined for both services. The "prices" for irrigation water and irrigation-related navigation and energy would be interdependent. Further constraints on one or the other price would be necessary to obtain a feasible solution. A range of solutions would have to be generated.

Cross-subsidization among countries may result when an inverse elasticity pricing approach is applied to the total cost allocation question. For example, the inverse elasticity pricing would establish proportionally higher "prices" for high-valued services (hydroelectricity, for example), and a low price for low-valued services (irrigation, for example). If one country consumed most of the hydroelectricity production, while another consumed most of the irrigation, the country consuming the hydroelectricity would be allocated a proportionally larger share of the repayment responsibility than the country using irrigation water.

Finally, the "optimal prices and quantities" are artificial, in the sense that the actual use of services within a given country are dependent on the financial conditions which exist. The allocation which results from this method represents only the marginal benefit and cost at the "optimal" quantity.

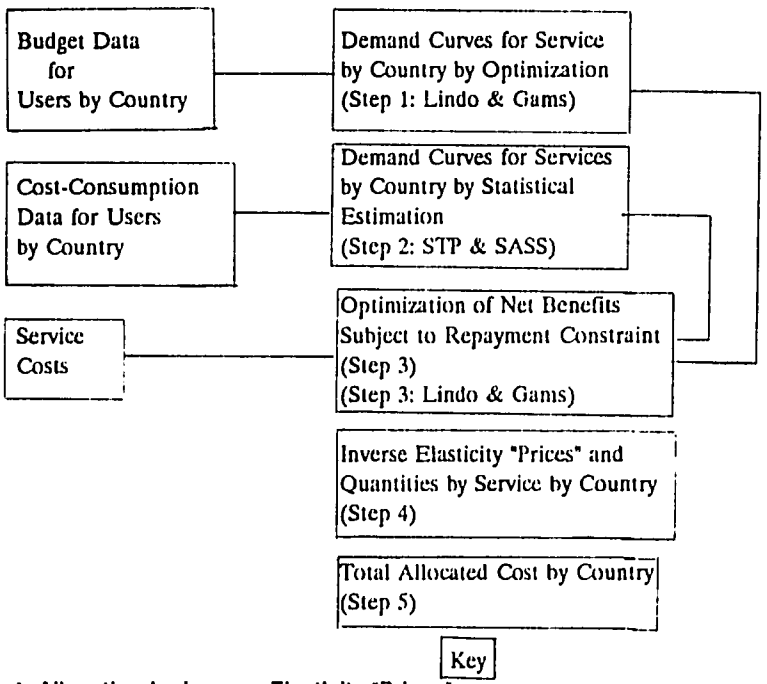

Figure 4. Allocation by Inverse Elasticity "Prices"

Allocation by full optimization

This approach would use a model which would maximize total net benefits to the OMVS program and would generate shadow values (implicit prices) for water. These shadow values would indicate the marginal value of the water.

However, it would be impossible to include each year of the time horizon in a PC optimization model. The existing P.C. optimization routines limit the size of the model to a significant degree; thus, aggregated data must be used.

Thus the optimization would have to be non-stochastic and would consider only average (expected) values for all prices, costs, and resource availabilities in order to be implemented on a P.C. Under these average conditions, the shadow value for water will be zero, or very close to zero. A zero shadow value means that transfers of water among users, or the provision of extra units of water, will not change total benefits. A cost allocation to countries cannot be made using such shadow values.

Furthermore, and most critically for cost allocation needs, the total repayment of project costs will occur automatically only if the sum of the marginal costs of services reflects all the project costs. Where joint production is involved, the marginal costs do not include the costs of the joint facilities. A constraint requiring that all costs must be repaid has to be included in the model. That constraint forces the prices determined by the optimization (the shadow values) to deviate from the marginal costs. The result is an inverse elasticity pricing system which has been described above.

These theoretical and empirical problems associated with full optimization indicate that such an option should not be contemplated.

Average Benefit Method

The USU cost allocation team was asked to develop a method which would be a compromise between the total benefit methods (ASCRB) and the inverse elasticity (IEP) methods which would take some account of marginal benefits but would be relatively easy to program and use. The average benefit method is a response to that request.

The allocation by average benefits is a compromise between the allocation by total benefits and allocation by the inverse elasticity method. The average benefit is an approximation of the midpoint of the demand curve for a service in a given country.[2] However, using this average value multiplied by the quantity consumed would not necessarily produce sufficient "revenue" to pay all project costs. Thus, a ratio of average benefits must be used for cost allocation.

There are two possible alternatives for implementing the average benefit method. The ratio of average benefits for each service or country to total average benefits could be applied directly to joint costs. Alternatively, this ratio could be used to adjust the remaining benefits calculated in the ASCRB method.

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[2]For a linear demand function, average remaining benefits do occur at the midpoint of the demand curve. For non-linear demand curve, they are an approximation.

Although either of the two approaches do reflect, to some extent, the marginal benefits, neither can be shown to always meet the economic efficiency and equity criteria. Figure 5 is a schematic diagram of the allocation procedure for this method.

Calculation of the Average Benefit Method: Separable costs would be subtracted from total justifiable costs to obtain the remaining benefits in each country, just as in the SCRB and ASCRB methods (*Steps 1 and 2*).

The average benefit would be calculated by dividing the total benefit by the use of the service (*Step 3*). A greater share of total service costs would be allocated to those countries in which the average benefit is greatest. Note that the average benefit times the average quantity used would not necessarily be sufficient to provide for the total costs. Therefore, a ratio must be calculated by which to allocate the joint costs of the project.

There two alternatives which could be used in this method are: First, the ratio of the average benefit of a given service or country to the total average benefit would be calculated, and that ratio used to allocate the joint costs. This alternative could allocate costs in excess of justifiable costs, as shown in the hypothetical example in Annex IV.

The second alternative would use the ratio of average benefits for a given service or country to the total average benefit to "adjust" the remaining benefits, as calculated in Step 2. This method also cannot be shown to meet the efficiency criteria. Because either approach may result in a failure to meet the economic efficiency criteria (criteria 2 or 3), an iterative procedure would need to be added to assure that the maximum allocated costs would be less than or equal to justifiable costs (that is, allocated joint costs would be less than or equal to remaining benefits). The remaining joint costs would be allocated to the other services or countries. The procedure would continue to iterate until all joint costs were allocated.

The key would be produced in the same way as for the SCRB and ASCRB methods (*Steps 4-6*).

No mater which alternative is chosen, a larger portion of the costs would be born by those services or countries which have higher average benefits. The key would, to some

degree, reflect the marginal values of services. The difference between a key generated by ARB and that of ASCRB would depend on the costs and benefits of a specific project.

The ARB method could be easily programmed into a user-friendly model on a PC, and would use the same data on which the ASCRB method is based. However, the iterative procedure for checking the efficiency criteria would be make the program somewhat more difficult to program and to operate.

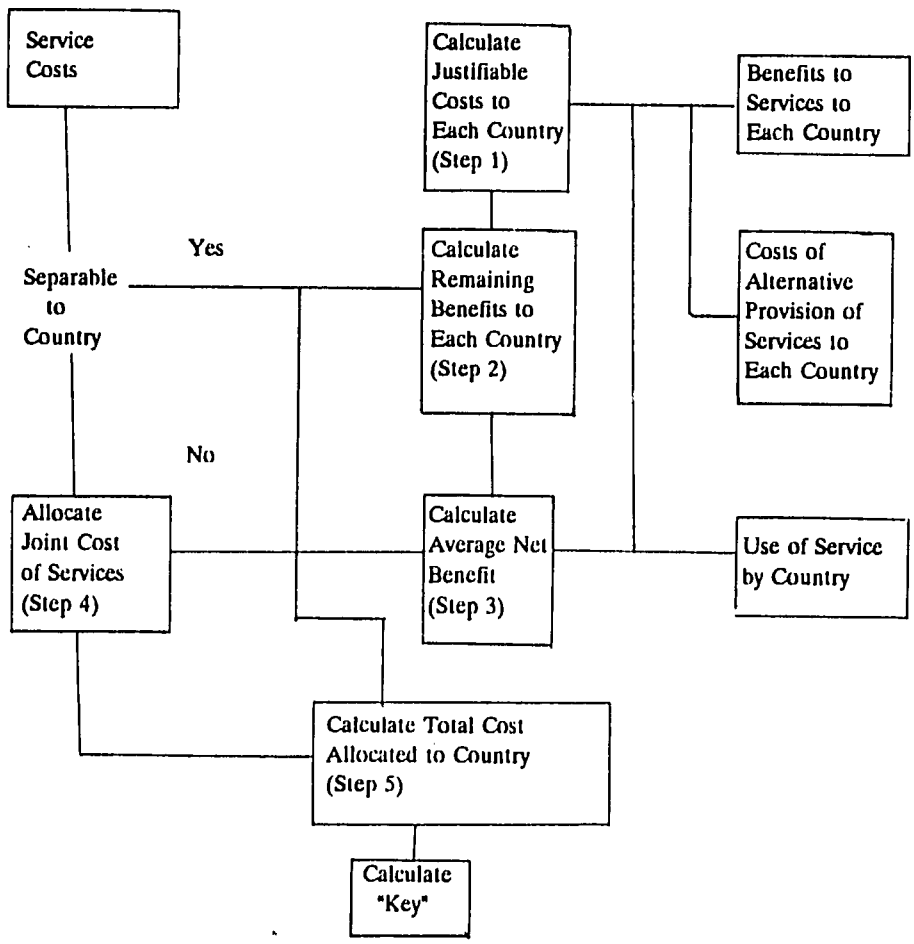

Figure 5. Allocation to Countries by Average Remaining Benefits

Table 3: Advantages and Disadvantages of the Different Methods

Methods of Cost Allocation to Country	Advantages	Disadvantages
Utilization of Facilities - Equal among the sectors - Proportional to the degree of use of facilities - By Priority	• Simple to program • Easy to use by untrained individuals • Minimal data base	• Economically inefficient • Inequitable and does not take into account the differences in benefits to users • Does not take account of marginal benefits and costs
Total Benefits - Net benefits - Justifiable Costs -SCRB - ASCRB	• Easy to program • Doesn't required trained personnel • Minimal data base required • Satisfies the criteria for economic efficiency • Conforms to the methods used in past allocations • Same advantages as SCRB and is more equitable	• Economically inefficient and inequitable • Does not consider marginal benefits or costs • SCRB not equitable (credit for cost savings in the common works) • Problems may occur with cross-subsidization •Not based on the marginal values
Average Benefit (ARB)	• Takes partial account of marginal benefits and cost • Can be programmed in a user-friendly model • Requires a minimum of data	• May fail the tests of economic efficiency • Ignores most of marginal costs and benefits
Marginal Benefits -IEP	• Economically efficient • Takes full account of marginal benefits and costs • Equitable	• Can not be modeled in a single, user-friendly model for untrained user • Requires good knowledge of the theory of optimization and programming • Not suited to cost allocation given actual use of services
- Global Optimization	• Economically efficient and equitable • Takes count of marginal benefits and costs	• Very difficult to program on PCs • Requires extensive data • Does not insure full repayment • Problems of dimensionality

Conclusion

Economic efficiency, equity, and the ease of programming and use are the criteria considered for the selection of a cost allocation method for recommendation to the Council of Ministers. Table 2 presents the advantages and disadvantages of the methods.

In view of the analysis presented in Appendix I and II, we recommend only the ASCRB method for allocating costs among countries because:

1. It is consistent with the method chosen by the Council of Minsters for allocating costs among services;
2. It can be shown that the method will never fail the criteria for economic efficiency and equity; and
3. It can be programmed easily into a user-friendly model which can be implemented on a PC.

APPENDIX III

The FAMM model has three fundamental objectives: to calculate a cost allocation key for services (water, energy and navigation) and among countries; to determine the use levels which will support the costs of the project which are allocated to them; and to provide a method to analyze the management of the debt during early periods of the program.

This part of the Synthesis Report includes a discussion of the development of the FAM model, criticisms of that model, and approaches to meet those criticisms.

Description of the FAMM model

Original FAMM model

Computer hardware and software. The original FAMM model was a computer program developed to apply the ASCRB method to the OMVS's Senegal River Basin Program. The model was written in FORTRAN code for execution on IBM and Digital Vax mainframe computers at USU. Three project services were examined: irrigation water, hydroelectricity and navigation. Report 1 (Utah State University, 1978) presents an exhaustive description of the original model.

Data Bases. For the purpose of estimating benefits, a combination of methods was operated to estimate benefits. Method 4 (net primary returns) was used for the agriculture sector using available farm budget information. Method 3 (Alternative costs) was used for the hydroelectricity and navigation services because little information was available on user budgets or willingness-to-pay.

Data were obtained from many existing publications as well as on-site visits to perimeters and research stations in the Senegal River Basin. All data were converted to economic values using IMF world price information and other data. The period of the

artificial flood was taken into account in the model. The benefits for irrigation were adjusted to account for the artificial flood during the transition period.

Labor costs were estimated using the average annual income of unskilled agricultural labor in the Senegal River Basin, as suggested by Gittinger (1974 and 1982). All values were calculated using a specified exchange rate between the U.S. dollar and the FCFA. No attempt was made to adjust for exchange rate fluctuations.

The data were reviewed and accepted by the OMVS and its Council of Ministers in 1977. Because the data were aggregated, the average benefits to irrigation water did not vary except for farm types (small and large perimeters). Distinctions in agricultural benefits among countries in the model were the result of hectares developed and the ratio of large to small perimeters. Transportation and energy transmission costs were evaluated. Examination of these data led to the conclusion that the average benefits to Hydroelectricity and navigation services would not vary significantly among the countries.

Report 1 (USU, 1978) and Report 6 (USU, 1984) review and discuss extensively the hydrology of the Senegal River. The analyses reveal that average water supplies would be adequate to meet all development needs, with the exception of the temporary provision for an important artificial flood during low flows periods.

Debt service costs were included. The actual interest rates charged were used. While these interest rates may not appear consistent with world prices, it was determined that the loans would not be available for alternative uses.

All costs and benefits were discounted at a 10 percent rate. The discount rate was reviewed and approved by OMVS and the Council of Ministers.

First update of the FAMM model

In 1982, the Council of Ministers and the OMVS requested that the program be made operational in Dakar, and that the data base be upgraded.

Computer hardware and software. Digital PDP 11/23 computers were provided to OMVS by USU. The FAM model was reprogrammed in DEC-based FORTRAN. The

basic algorithms and cost allocation procedures were not altered. A complete description of the model and its use may be found in Report 6 (USU, 1984, particularly Volume II, the User's Manual).

Extension of the data base. As a part of the reprogramming, the model was expanded to include environmental costs and a loan management component. The latter has been called the loan management sub-model. However, its purpose was to calculate the loan repayment distribution including the interest payment schedule associated to each loan. These interest charges were used in the cost allocation process. The loan management sub-model was not meant to be used as an accounting tool for OMVS. Loan balances and costs were calculated, but these balances were based on the average user fees. The analysis was economic, not financial.

Environmental costs were based on publications by and personal communication with Gannett Flemming (1979). Many of the costs reported in that study were qualitative. They could not be used in the FAMM model. Economic losses were estimated for the reduced availability of forests and fisheries, and relocation of villages from the dam sites. However, costs for other environmental considerations, such as health and social costs, could not be estimated and were not included in the FAM model. Note that these environmental costs were not included in the recalculation of the key.

The discount rate could be varied by the user of the model. If the user did not specify a discount rate, a 5% discount rate was used.

All data used in the model were examined and approved by the OMVS personnel during its reprogramming in 1983 and 1984 in Dakar.

This new FAMM model was designed to have maximum flexibility in terms of routines manipulation. It was composed of 12 sub-models, many of which required intervention by the operator. Results from each sub-model could be examined separately. The model provided opportunities to vary assumptions about the timing of development, delays in construction, and the distribution of irrigation water, hydroelectricity, and navigation services.

The model's structure required an operator who was well trained in both cost allocation and in the operation of the model.

Second update of the FAMM model

Refinement of the data base. In 1986, the UNDP financed another update of the FAM model and recalculation of the key (Report 7 Utah State University, 1987). Costs used in the updated model were based on data found in other publications and on primary data collected for the study. The most current data from various publications (Beauchemin, 1985; Groupement Manantali, 1985; Ministère du Développment Rural, République du Senegal, 1986; GIBB/EDF/EC, Reports 1 and 2, 1987) were included. In the agricultural sector, costs and prices were available from several other sources. These data, when adjusted to economic values, did not appear to be significantly different from the data used in Report 6. All other prices and costs were adjusted to world prices when such an adjustment was necessary. All the data used in Reports 6 and 7 were examined and approved by OMVS personnel in 1986 and 1987.

However, this new data base was not used in the recalculation of the key in 1986.

Cost Allocation Procedures in the FAMM Model

Allocations in the FAMM model were based on averaged data. The joint cost allocation was determined from total remaining benefits. Service costs were allocated to countries based on the consumption. Therefore, the key was also based on averaged data.

Figure 7 is a schematic diagram of the cost allocation procedures in the FAM model. It is based on the description of the ASCRB method given in Annex III.

Benefits and alternative costs were compared for each service to obtain justifiable costs (*Step 1*).

Separable costs were then subtracted from justifiable costs to obtain remaining benefits (*Step 2*).

The adjustment was applied to separable costs and the resulting remaining benefits were used to allocate the joint costs (*Step 3*).

Once the costs were allocated to each of the three services, an average "user fee" per unit of each service was calculated by dividing the allocated costs by the use for each service (*Step 4*). These calculated user fees have a very limited definition. They were the average costs of each service; they were not recommended tariffs.

Each user fee was multiplied by the projected annual use of that service for each country (*Step 5*). The repayment responsibility for each country was then calculated by summing the repayment responsibility for each service in that country. The average "user fees" were consistent with the assumption of constant average benefits for each service and country, and fulfilled the conditions for the use of services method of cost allocation. The proportion of total repayment responsibility was calculated for each country, and reported in the key.

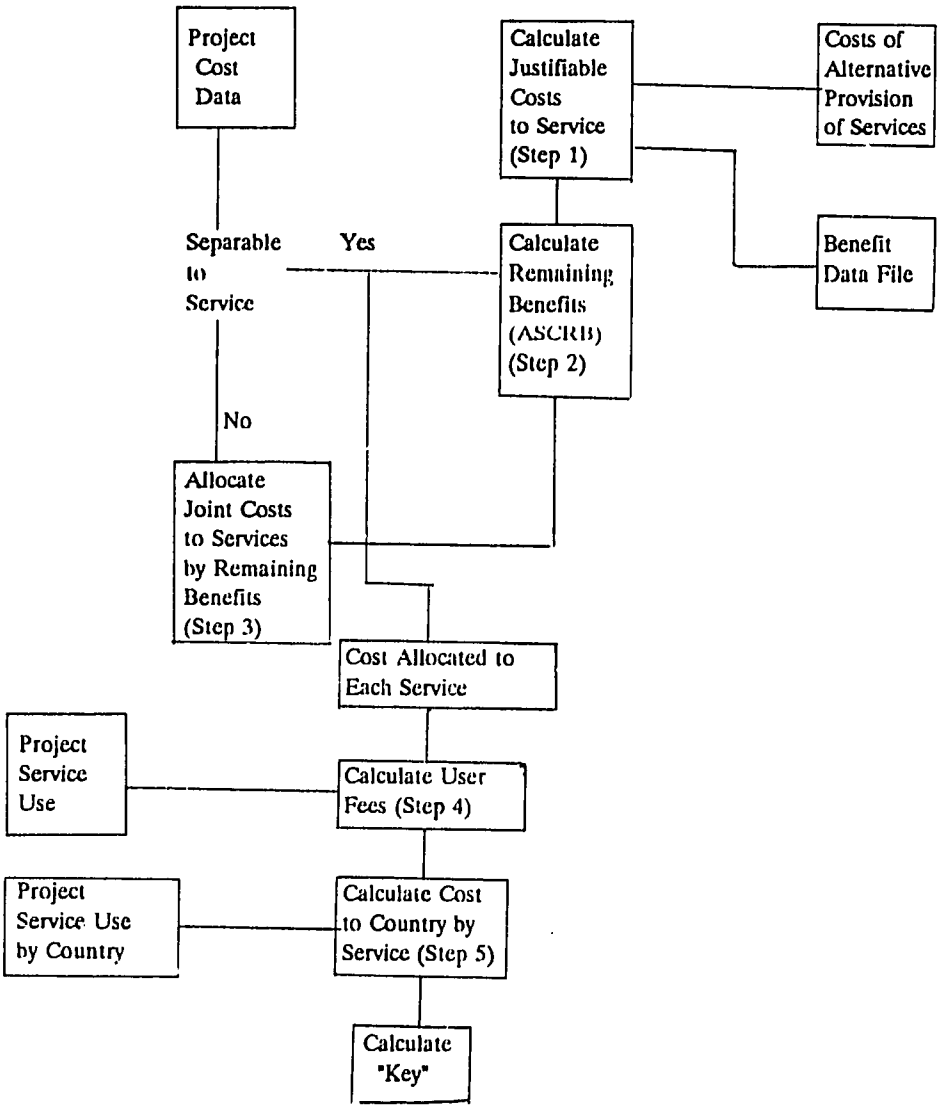

Figure 6. FAM Model

Criticisms of the FAM Model

The current FAM model partially met the three objectives cited; however, there remain modifications which should be performed. There have been several criticisms of the model, many of which were reported in an analysis by GIBB/EDF/EC (Rapport de demarrage, 1986), indicated below:

- *The model did not apply to the existing situation in each country and the accounting module was applicable only in a macroeconomic sense.* This observation was correct. However, the model was developed for allocation of costs on an economic basis, not to establish tariffs using a financial analysis. The function of the loan module was to determine the interest payments and charges for the loans, rather than provide OMVS with an accounting tool. However, the objectives of the loan module were not clearly identified and misinterpretations resulted.
- *The model and its guide were difficult to comprehend and use.* These criticisms were valid. However, the problems encountered as a result of the inherent constraints and objective of the programming resulted in many of these problems.

In order to be as exhaustive as possible, the users' manual attempted to furnish the theory of cost allocation, directions for the use of the model, and the FORTRAN programming as well. While these objectives were ambitious, the result was a manual which was too long and too complex for insufficiently trained personnel.

The model attempted to incorporate a wide range of alternatives for both development scenarios and data bases. As a result, many of the modules required user intervention and transferring results of one module to the next. The complexity of the FAMM model and the required technical expertise rendered the model less useful to the OMVS personnel than was expected.

- *The model did not permit a continuous run to the calculation of the key.* The model also did not provide directions or menus in French.
- *The key was calculated separately from the model and the user was required to manually enter the data.* This observation is correct.
- *The model did not include an explicit hydrologic component.* The studies completed by Utah State University, ORSTOM, and GIBB/EDF/EC all indicate that for the average annual conditions, water availability is sufficient

to provide for all the projected services. The only exception occurs during the artificial flood, when electrical generation may have to be reduced under drought conditions. However, since the FAM model was constructed for these average conditions, there was no need to explicitly include a hydrologic model. Note, however, that diversions and consumptive use of water was calculated in the model (and could have been printed out). The model assumed a single, homogeneous basin, for which releases at Manatali, consumptive use, and outflows at Diama were all of the hydrologic information necessary.

Microeconomic impacts of the repayment obligations were not considered. This criticism is correct, in that the model did not analyze pricing of services or its impacts. However, as discussed above, cost allocation is not a financial analysis, and the microeconomic impacts are not a part of cost allocation. Never-the-less, the determination of the capacity of users to pay for project services is a critical issue, particularly give the financial difficulties which confront the member states.

A microeconomic analysis was undertaken by GIBB/EDF/EC at the request of OMVS for the initial phase of the project. Tariffs were calculated based on the ability of users of the project services to pay for them, based on various assumptions regarding the development of the basin. This work appeared to be well founded, but it applied only to the initial period of the project and did not provide a model.

Reprogramming the FAM model

In order to correct the shortcomings which have been identified, the following solutions are proposed:

1. *Method and computer hardware and software.* It is proposed that the model use the ASCRB method for allocating the costs among services and countries. This approach has been identified as the most desirable alternative, and can be programmed on

PCs.

The model will be programmed in C language. This language allows greater flexibility in treatment of data bases and in the construction of menus. The model will be menu-driven in French, more user-friendly, and better adapted to the current conditions. A new, easier-to-use manual will be developed.

Since the PDP 11/23 computers are no longer functional, IBM System 2 PCs have been provided to the OMVS which are compatible with the organization's existing equipment and skills.

2. *Extensions of the model.*

Hydrologic Model. An explicit water balance will be included as part of the model. This water balance will consider water releases from the Manantali Dam, diversions along the river in each region, consumptive use and return flows, and the outflows from the upstream regions to the downstream regions. To be consistent with the rest of the allocation process, the model will be based on average annual values. It does not appear that the average annual availability will constrain the services (GIBB/EDF/EC, 1987).

New Use Sectors. New use sectors will be considered such as municipal and industrial (M&I) water supplies and alternative uses of energy. The model will also will specify regions and farm types, and the livestock production data will be re-examined.

Financial models. Models will be developed for both financial, or microeconomic, analysis and for loan management during Phase II.

3. *Microeconomic analysis.* The proposed microeconomic analysis is based upon the ability of users to pay for services at a given time.

An obvious choice of modelling approach is the inverse elasticity methodology, using financial data. The approach requires that demand and marginal cost curves be known or estimated for users of each service. Maximizing consumers' plus producers' surplus subject

to the constraint that the allocated service costs be repaid would generate optimal tariffs and quantities of use.

If the repayment constraint could not be met by users, the solution would be infeasible. The repayment requirement would be lowered until users could generate sufficient capacity to pay the assigned costs. Some incentive for using the project services would have to be maintained at the same time. This approach would identify the optimal tariffs and use levels for each service in each country.

A second approach to the microeconomic analysis would be based on a general accounting approach. Tariffs would be calculated by examining budgets of users or alternative costs of providing the same service (as in GIBB/EDF/EC, 1987). A computer model could be developed which would solve the problem of setting feasible tariffs. This model would be a first-order approximation of the inverse elasticity approach.

The data requirements for the microeconomic analysis also depend on the level at which the tariffs are expected to be set. If the analysis is to be accomplished for a single supranational agency, then a single model would be developed using aggregated data. A model for each country would be required if the tariffs are to be set by member states. Country-specific data would be necessary.

Institutional constraints, such as pricing policies, could be analyzed. The initial development may examine a limited set of these existing financial constraints.

4. *Loan management model.* The second part of the analysis is the "loan management" model. This model would be similar to the model developed for the FAM model in 1983-84, but it would use financial data. Report 6 (Utah State University, 1984) contains a full description of the loan management sub-model. This model would calculate the loan repayment requirements for each country for each time period. The difference between the requirements and the revenues generated from the microeconomic model would determine the contributions of each country. The portion of contributions which would be considered "social overhead investment" and the portion considered direct subsidy would be up to each member state.

No matter which approach is taken, it is doubtful that these initial models can be user friendly because considerable detail will be necessary for the analysis and because the required programming will be complex.

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GLOSSARY

Economic efficiency: concept relating to the level and structure of prices to be costs, in which marginal benefits equal marginal costs. This results in the maximization of benefits being obtained. For many water projects, economic efficiency is measured globally by the benefit/cost ratio.

Cost stream: A series of cost values extending over a period of time, generally several years

Benefit stream: A series of benefit values extending over a period of time, generally several years.

Services: The products or outputs of a development project, such as irrigation water supply, hydroelectricity, and navigation.

Use sectors (or economic sectors): Use or market area of a particular service (such as electrical energy) provided by a project.

Specific costs: are the costs of those physical facilities (inputs) which are required exclusively by a particular identifiable service (for example, canals with irrigation or turbines and transmission lines with hydroelectricity). All costs associated with Diama dam are specific costs since they are assigned to water supply.

Imputed Costs: Costs of the common works which can be allocated to specific services or countries based on a "with"-"without" cost comparison.

Separable costs: The separable costs are the specific costs plus any portion of the cost of the joint inputs (such as a dam) which can be legitimately allocated to a specific service (imputed costs) [(1) + (2)].

Joint costs: are the costs of the joint inputs which cannot be assigned to any specific service. These are the remaining costs when separable costs are subtracted from total project costs.

Alternative costs: The costs of the least-cost single-purpose project which will provide the same service.

Justifiable costs: The lessor of the benefits generated by the service or in the country and the alternative costs for that service and/or country.

Equity: Fair allocation among participants of the costs and benefits of a shared water resources development program.

KEY: Values which provide each country 's share of repayment responsibilities for the total project costs.

APPENDIX IV - EXAMPLE PROBLEM OF COST ALLOCATION

The following hypothetical example is used to illustrate the various methods of calculating benefits and costs, cost allocation, calculation of the key, and retroactivity of the key. It is not meant to represent actual conditions in the Senegal River Basin. Note that, in some cases, steps in these calculations have been given a title. These titles are not used as world-wide standard practice in cost allocation, and, therefore, are not included in a glossary.

Calculation of Separable and Joint Costs

The following data will be used in the example problem:

The total cost of the project is 700 units.
The life of the project is 30 years.
The cost of construction of the multipurpose dam (irrigation, energy, and navigation) is 450 units and the annual cost of operation, maintenance and replacement is estimated as 3.253 units.

The rate of interest is 5%.

The cost of canals and other works specific to irrigation are 5 units, with 0.325 units for OM&R. The least cost alternative for the irrigation services is 200 units.

The cost of construction of the central energy facility and transmission lines is 75 units; The annual cost of OM&R are 1 .626. The least cost alternative for energy is 600 units.

The cost of construction of barges and ports is 50 units with an annual OM&R cost of 2.602. The least cost alternative for navigation service is 200.

The cost of a dam for water supply and navigation only at the same site is 300 units.

The costs of a dam for navigation only at the same site is 280.

The cost of a dam for water supply only at the same site is 240 units.

Calculation of Specific and Joint Costs

(1) Total Costs = 700

(2) Costs of the dam
- (2a) Investment = 450
- (2b) Operation and Maintenance per yr = 3.253
- (2c) Present Value of O and M for 30 yrs = 50
- (2d) Total costs of the dam = 500

(3) Costs of the alternative dams
- (3a) Costs of water supply and Navigation = 300
- (3b) Costs of water supply only = 240
- (3c) Costs of navigation only = 280

(4) Specific Costs

		Water Supply(ws)	Energy	Navigation
(4a)	Investments	5	75	50
(4b)	Operation et Maint per yr	0,325	1,626	2,602
(4c)	Present Value O & M	5	25	40
(4d)	Specific Costs (2a)+(2c)	10	100	90

(5) Imputed Costs
- (5a) Imputed Costs to Energy = (1) - (3a) = 500-300=200
- (5b) Imputed Costs to Water Supply = (3a) - (3c) = 300 - 280 = 20
- (5c) Imputed Costs to Navigation = (3a) - (3b) = 300 - 240 = 60

(6) Separable Costs

	wp	Energy	Navigation
(4d) + (5)	10+20=30	100+200=300	90+60=150

(7) Joint Costs = (1) - ((5a)+(5b)+(5c)) = 700 - (30 + 300 + 150) = 700 - 480 = 220

ALLOCATION OF COSTS TO SERVICES

Benefits realized by the users of services of the project:

Agriculture

The project permits the production of rice, which earns the peasant farmers a net return of 300 dollars per ton ($0.30/kg). Production of irrigated rice is 4 tons per hectare (for a total of $1,200 per hectare).

Irrigated rice replaces the existing sorghum production, which earned the farmers 252 dollars per ton ($0.252 per Kg). The average production of sorgum is 1.5 ton per hectare ($378 per hectare).

The project permits 791.363 hectares to be irrigated.

The net benefit to agriculture equals the value per year of rice ($1.200 * 791,363 = $949 635) less the value of the existing production of sorghum ($378 * 791,363 = $299 135) for the irrigated areas [($949 635 - $299 135)=$650 500] for which the present value for 30 years is $10 000 000 (100 units of $100 000 per unit). It is assumed that all countries have the same soil types and costs of production.

The total use of water is 2 058 088.4 meters^3

Energy

The alternative for production of energy is thermal energy, for which the costs varies by country. The cost of thermal energy is: $0.2911/Kwh in Country A,$0.2602 in Country B, and $0.4337/Kwh in Country C. The capacity of the hydropower plant is 1.5 mégawatts, which, with an efficiency of 76%, furnishes 1.14 megawatts, or 10 000 000 Kilowatt per hour. The annual benefits are:

Country A: 4 500 000 kwh x .2911= 1 301 000 (13.01 units); Present Value = 200
Country B: 2 500 000 kwh x .2602= 650 500 (6.505 units); Present Value = 100
Country C: 3 000 000 kwh x .4337= 1 301 000 (13.01 units); Present Value = 200

The annual total value is 32.525 units and the utilization is 100 units. The present value of total benefits is 500 units.

Navigation

The least cost alternative to navigation is assumed to be by truck. The cost of transport per ton-kilometer varies by country and depends on the state of the roads. The cost of transport per ton-kilometer is: $0.32525 in Country A, $0.36592 in Country B and $0.34143 in Country C.

The volume of annual transport is: 2 000 000 t-k in Country A,
1 333 000 t-km in Country B and 3 333 300 t-km in Country C.

The annual benefits are:

Country A: 2 000 000 x .32525= 650 500 (6.505 units); Present Value = 100
Country B: 1 333 000 x .36592= 487 890 (4.8789 units); Present Value = 75
Country C: 3 333 333 x .34143= 1 138 000 (11.38 units); Present Value = 175

Total annual value is 22.764. total annual utilization is 66,66333 units.

The present value of benefits is 250 units.

Summary of Benefits, Alternative Costs, and Separable Costs

(Values in units of $100 000)

	Irrigation	Energy	Navigation
Benefits	100	500	350
Alternative Costs (given above)	200	600	200
Separable Costs to services	30	300	150

Allocation of Costs to Services

		Irrigation	Energy	Navigation
(1)	Total Costs = 700			
(2)	Benefits	100	500	350
(3)	Alternative Costs	200	600	200
(4)	Justifiable Costs min ((2),(3))	100	500	200
(5)	Separable Costs	30	300	150
(6)	Joint Costs = 700 - 480 = 220			
(7)	Justifiable Costs to other services min [Sum (4) without service in question or (1)-(5)]	670	300	550
(8)	Total Justifiable Costs (4)+(7)	770	800	750
(9)	Adjustment factor (8)/(1)	1.100	1.14286	1.07143
(10)	Adjusted Separable Costs (5)*(9)	33	342.857	160.714
(11)	Adjusted Remaining Benefits (ASCRB) (4)-(10)	67	157.143	3.9286
(12)	Total adjusted remaining benefits = Sum (11) = 263.429			
(13)	Allocation ratio (ASCRB) (11)/(12)	.2543	.5965	.1491
(14)	Remaining Benefits (SCRB) (4)-(5)	70	200	50
(15)	Total Remaining Benefits (SCRB) = Sum (14) = 70 + 200 + 50 = 320]			
(16)	Allocation ratio (SCRB) (14)/(15)	.21875	.625	.15625
(17)	Allocated Joint Costs (ASCRB) (6)*(13)	55.95	131.24	32.81
(18)	Total Allocated Costs (ASCRB) (17)+(5)	85.95	431.24	182.81
(19)	Allocated Joint Costs (SCRB) (6)*(16)	48.125	137.60	34.375
(20)	Total Allocated Costs (SCRB) (19)+(5)	78.125	437.50	184.375

ARB

There are two alternatives proposed for the ARB method. The alternatives begin by using the same data as the ASCRB method.

		Irrigation	Energy	Navigation
(1)	Total Costs = 700			
(2)	Benefits	100	500	350
(3)	Alternative Costs	200	600	200
(4)	Justifiable Costs min ((2),(3))	100	500	200
(5)	Separable Costs	30	300	150
(6)	Joint Costs = 700 - 480 = 220			
(7)	Total Benefits per year	6.505	32.525	22.764
(8)	Quantity of Total Service per year	20.58088	100	66.66
(9)	Average Benefits per year (7)/(8)	.31607	.32525	.34146
(10)	Total des Bénéfices Moyens = .31607 + .32525 + .34146 = .98278			
(11)	Average Benefit$_j$ to Total Average Benefits (9)/(10)	.32161	.33095	.34744

Alternative N° 1

(12)	Allocated joint costs by ratio BM$_j$ to BM Total (6)*(11)	70.75	72.81	76.44
(13)	Total Allocated Costs (5)+(12)	100.75*	372.81	226.44*

*Total allocated costs are greater than the justifiable costs (13) > (4).

(14)	Maximum Costs allowed by Criteria 1		100	200
(15)	Allocated Total Costs	100	400	200

Alternative N° 2

(16)	Remaining Benefits (4)-(5)	70	200	50
(17)	Ratio BM$_j$ à BM Total (11 above)	.32161	.33095	.34744
(18)	Remaining Benefits adjusted by Ratio (16)*(17)	22.513	66.190	17.372

(18)	Adjusted total remaining benefits = Sum (18) = 106.075			
(19)	Ratio of adjusted remaining benefits to total remaining benefits (17)/(18)	.2123	.6240	.1637
(20)	Allocated Joint Costs (6)*(19)	46.71	137.28	36.01
(21)	Total Allocated Costs (5)+(20)	76.71	437.28	186.01

Allocation of Costs to Countries by ASCRB Method

By Utilization of Services

(1) Consumption of Services by Country Per Year (Given)

Country	Irrigation		Energy		Navigation	
	Amount	Percent	Amount	Percent	Amount	Percent
A	12.035	60	45	45	20	30
B	6.174	30	25	25	1.333	20
C	2.058	10	30	30	3.333	50
TOTAL	100	100	100	100	66.66	100

(2) Separable Costs by Country (Given)

Country	Irrigation	Energy	Navigation
A	0	0	25
B	0	50	10
C	0	50	25

(3) Costs allocated to service by the ASCRB Method - line (18)

(3a) Irrigation = 85.95
(3b) Energy = 431.24
(3c) Navigation = 182.81

(4) Allocation by Percentage of Utilization of Services (percentage of utilization multiplied by the costs allocated to each service; (1 in percent)*(3) for each service and each country.

Country	Irrigation	Energy	Navigation	Total	"KEY"
A	51.57	194.06	54.84	300.47	42.92%
B	25.785	107.81*	36.56	170.155	24.31%
C	8.595	129.37	91.41	229.375	32.77%
TOTAL	85.95	431.24	182.81	700.00	100.00%

*allocation exceeds justifiable costs

Allocation of Costs to Countries by ASCRB Method

Calculation of benefits

(1) Agriculture. Note that the benefits are proportional to the utilization of water, because the soils and production are the same in each country.

(1a) Country A. (1) * (3) = 0,60 * 100 = 60
(1b) Country B. (1) * (3) = 0,30 * 100 = 30
(1c) Country C. (1) * (3) = 0,10 * 100 = 10

(2) Energy

(2a) Country A: 4 500 000 kwhx.2911= 1 301 000 (13.01 units);
Present Value = 200
(2b) Country B: 2 500 000 kwhx.2602= 650 500 (6.505 units);
Present Value = 100
(2c) Country C: 3 000 000 kwhx.4337= 1 301 000 (13.01 units);
Present Value = 200

(3) Navigation

(3a) Country A: 2 000 000 x .32525= 650 500 (6.5 units);
Present Value = 100
(3b) Country B: 1 333 000 x .36592= 487 890 (4.8789 units)
Present Value = 75
(3c) Country C: 3 333 333 x .34143= 1 138 000 (11.38 units)
Present Value = 175

Irrigation - Allocation of the Total Cost of 85.95

The alternative costs of furnishing the irrigation service in each country is as follows: 50 for Country A, 50 for Country B and 20 for Country C.

		Cnty A	Cnty B	Cnty C
(1)	Total Costs = 85,95			
(2)	Benefits	60	30	10
(3)	Alternative costs	50	50	20
(4)	Justifiable costs min((2),(3))	50	30	10
(5)	Separable Costs	0	0	0 (no adjustment necessary; SCRB=ASCRB)

(6)	Remaining Benefits (4)-(5)	50	30	10
(7)	Total Remaining Benefits = Sum (6) = 50 + 30 + 10 = 90			
(8)	Allocation Ratio (6)/(7)	.556	.333	.111
(9)	Joint Costs = Total Costs to Irrigation - Separable Costs =(1) - (5) = 85,95			
(10)	Allocated joint costs (8)*(9)	47.78	28.62	9.55
(11)	Total Costs (test) = Sum (10) = 85,95			

Energy - Allocation of Total Cost of 431,24

The alternative costs of production of energy in each country are as follows: 250 in Country A, 150 in Country B, et 250 in Country C.

		Cnty A	Cnty B	Cnty C
(1)	Total Costs = 431,24			
(2)	Benefits	200	100	200
(3)	Alternative costs	250	150	250
(4)	Justifiable costs Min [(2),(3)]	200	100	200
(5)	Separable costs (Given)	100	50	50
(6)	Justifiable costs to other services Sum (4)-(4)	300	400	300
(7)	Total Remaining costs (1)-(5)	331.24	381.24	381.24
(8)	Minimum absolute Min[(6),(7)]	300	381.24	300
(9)	Adjustment factor (8)+(4)/(1)	1.1594	1.1159	1.1594
(10)	Adjusted separable costs (5)*(9)	115.94	55.80	57.97
(11)	Remaining benefits (4)-(10)	84.06	44.20	142.03
(12)	Total remaining Benefits = Sum (11) = 270.29			

(13)	Allocation ratio (11)/(12)	0.3110	0.1635 ·	0.5255
(14)	Joint costs = (1) - Sum (5) = 431.24 - 200 = 231.24			
(15)	Allocated joint costs (13)*(14)	71.92	37.81	121.51
(16)	Total allocated costs (5)+(16*	171,92	87,81	171,51

Navigation - Allocation of Total Cost of 182,81

The alternative costs for navigation in each country are as follows: 80 in Country A, 70 in Country B, and 200 in Country C.

		Cnty A	Cnty B	Cnty C
(1)	Total costs = 182.81			
(2)	Benefits	100	75	175
(3)	Alternative costs	80	70	200
(4)	Justifiable costs Min [(2),(3)]	80	70	175
(5)	Separable costs (Given)	25	10	25
(6)	Justifiable costs to other services Sum (4)-(4)	245	255	150
(7)	Total remaining cost (1)-(5)	157.81	172.81	150
(8)	Minimum absolute Min[(6),(7)]	157.81	172.81	150
(9)	Adjustment factor (8)+(4)/(1)	1.3010	1.3282	1.7780
(10)	Adjusted separable costs (5)*(9)	32.52	13.28	44.45
(11)	Remaining benefits (4)-(10)	47.48	56.72	130.55
(12)	Total remaining Benefits = Sum (11) = 234.75			
(13)	Allocation ratio (11)/(12)	0.2023	0.2416	0.5561
(14)	Joint Costs = (1) - Sum (5) = 182.81 - 60 = 122.81			

(15)	Allocated joint costs (13)*(14)	24.84	29.67	68.30
(16)	Total allocated costs (5)+(15)	49.84	39.67	93.90

Key Determined by the ASCRB Method

Country	Irrigation	Energy	Navigation	Total	"KEY"
A	47.78	171.92	49.84	269.54	38.51%
B	28.62	87.81	39.67	156.10	22.30%
C	9.55	171.51	93.30	274.36	39.19%
TOTAL	85.95	431.24	182.81	700.00	100.00%

3. Allocation to Countries by the ARB Method

This example uses the calculations of remaining benefits from the ASCRB method above.

Irrigation

		Cnty A	Cnty B	Cnty C
(1)	Total Costs = 85.95			
(2)	Separable costs	0	0	0
(3)	Utilization	12.348	6.174	2.058
(4)	Benefits	60	30	10
(5)	Annual benefits	3.903	1.952	0.6505
(6)	Remaining benefits	50	30	10
(7)	Annual average benefits (4)/(3)	0.316	0.316	0.316
(8)	Total remaining benefits = Sum (6) = 90			

Alternative N° 1 - Allocation by average ber ·fits

(9)	Allocation ratio (4)/(5)	0.333	0.333	0.333
(10)	Joint costs = (1)-Sum (2) = 85.95			
(11)	Allocated joint costs (10)*(9)	28.65	28.65	28.65*

*exceeds the benefits. This method fails the economic efficiency test of criteria 1.

Alternative N° 2 - Allocation by adjusted remaining benefits

This alternative utilizes the percentage of average benefits to adjust the remaining benefits. Countries with high average benefits are assigned higher costs than countries with lower average benefits. There is, however, no guarantee that the allocated costs will not exceed benefits.

		Cnty A	Cnty B	Cnty C
(12)	Adjusted Remaining benefits (6)*(7)	15.80	9.480	3.160
(13)	Total adjusted remaining benefits = Sum (10) = 28.44			
(14)	Allocation ratio (12)/(13)	0.556	0.333	0.111
(15)	Allocated joint costs (8)*(14)	47.75	28.65	9.55

Energy

(1)	Total costs = 431.24			
(2)	Separable costs	100	50	50
(3)	Utilization	45	25	30
(4)	Annual benefits	13.01	6.505	13.01
(5)	Remaining benefits	100	50	150
(6)	Annual Average benefits (4)/(3)	0.2911	0.2602	0.4337
(7)	Total remaining benefits = Sum (6) = 0.9830			
(8)	Adjusted remaining benefits (5)*(6)	29.11	13.01	65.05
(9)	Total adjusted remaining benefits = Sum (8) = 107.07			
(10)	Allocation ratio (8)/(9)	0.2716	0.1214	0.6069
(11)	Joint costs = (1)-Sum (2) = 431.24 - 200 = 231.24			
(12)	Allocated joint costs (10)*(11)	62.81	28.08	140.35
(13)	Total allocated costs (2)+(12)	162.81	78.08	190.35

Navigation

(1)	Total costs = 182.81			
(2)	Separable costs	25	10	25
(3)	Utilization	20	13.333	33.333
(4)	Annual benefits	6.505	4.8789	11.38
(5)	Remaining benefits	55	60	150
(6)	Average Annual benefits (4)/(3)	0.32525	0.36592	0.34134
(7)	Total Average annual benefits = Sum (6) = 1.03251			
(8)	Adjusted remaining benefits (5)*(6)	17.888	21.955	51.201
(9)	Total adjusted remaining benefits = Sum (8) = 91.044			
(10)	Allocation ratio (8)/(9)	0.1965	0.2411	0.5624

(11)	Joint costs = (1)-Sum (2) = 182.81 - 60 = 122.81			
(12)	Allocated joint costs (10)*(11)	24.13	29.61	69.07
(13)	Total allocated costs (2)+(12)	49.13	39.61	94.07

Key - ARB Method - Alternative No.2

Country	Irrigation	Energy	Navigation	Total	"KEY"
A	47.75	162.81	49.13	259.69	37.10%
B	28.65	78.08	39.61	146.34	20.91%
C	9.55	190.35	94.07	293.97	41.99%
TOTAL	85.95	431.24	182.81	700.00	100.00%

Allocation of Costs by Inverse Elasticity

The mathematical formulation of this method is given in the following expressions:

$$\underset{\forall j}{\text{Maximize}} \Sigma_t \, 1/(1+r)^t \; \Sigma_i \int_{Qj} [P_{ij}(Q_{ij}) - \text{Marginal Cost}_{ij}(Q_{ij})] dQ_j$$

Subject to:

$$\Sigma_t \, 1/(1+r)^t \; \Sigma_i \Sigma_j \, P_{ij} * Q_{ij} \geq \text{Total Project Cost}$$

$$\Sigma_t \, 1/(1+r)^t \; \Sigma_i \, P_{ij} * Q_{ij} \geq \text{Separable Costs}_j$$

$$\Sigma_t \, 1/(1+r)^t \; \Sigma_i \, P_{ij} * Q_{ij} \leq \text{Justifiable Costs}_j$$

where:

t = time
i = country
j = service
r = rate of interest

The results are the optimal P_{ij}^*, Q_{ij}^* for all i, j

The allocated total cost to a country is $\Sigma_j P_{ij}^* Q_{ij}^*$ for all i

The key is $\Sigma_j P_{ij}^* Q_{ij}^*$ / Total project cost for each i

Demand curves for irrigation

Cnty A : QAI = 31.842 - 3.98 * PAI; or PAI = 8 - .25124 * QAI;
Cnty B : QBI = 13.61 - 3.4025 * PBI; or PBI = 4 - .2939 * QBI;
Cnty C : QCI = 6 - PCI; or PCI = 6 - QCI.

Demand Curves for Navigation

Cnty A : QAN = 37.895 - 4.737 * PAN; or PAN = 8 - .21111 * QAN
Cnty B : QBN = 37.647 - 9.412 * PBN; or PBN = 4 - .10625 * QBN
Cnty C : QCN = 70.588 - 11.765 * PCN; or PCN = 6 - .085 * QCN

Demand Curves for Energy

Cnty A: QAE = 68.517 - 0.685 * PAE; or PAE = 100 - 1.4595 * QAE
Cnty B: QBE = 38.527 - 0.771 * PBE; or PBE = 50 - 1.2978 * QBE
Cnty C: QCE = 47.647 - 1.191 * PCE; or PCE = 40 - .8395 * QCE

The model is formulated for GINO, and is given as follows:

MAXIMIZE = 8 * QAI - .12562 * QAI ^ 2 + 6 * QBI - .1469 * QBI ^ 2 + 6 * QCI - .5 * QCI ^ 2 + 8 * QAN - .10556 * QAN ^ 2 + 4 * QBN - .05313 * QBN ^ 2 + 6 * QCN - .0425 * QCN ^ 2 + 100 * QAE - .7298 * QAE ^ 2 + 50 * QBE - .6489 * QBE ^ 2 + 40 * QCE - .41975 * QCE ^ 2 - PAYMENT;

[SUBJECT TO:]

Project reimbursement constraint:

2) 8 * QAI - .25124 * QAI ^ 2 + 4 * QBI - .2939 * QBI ^ 2 + 6 * QCI - QCI ^ 2 + 8 * QAN - .211111 * QAN ^ 2 + 4 * QBN - .10625 * QBN ^ 2 + 6 * QCN - .085 * QCN ^ 2 + 100 * QAE - 1.4595 * QAE ^ 2 + 50 * QBE - 1.2978 * QBE ^ 2 + 40 * QCE - .8395 * QCE ^ 2 = 700;

Justifiable costs constraints:

	Irrigation	Energy	Navigation
Cnty A	50	200	80
Cnty B	30	100	70
Cnty C	10	200	175

3) 8 * QAI - .25124 * QAI ^ 2 < 50 ;
4) 4 * QBI - .2939 * QBI ^ 2 < 30 ;
5) 6 * QCI - QCI ^ 2 < 10 ;
6) 8 * QAN - .21111 * QAN ^ 2 < 80 ;
7) 4 * QBN - .10625 * QBN ^ 2 < 70 ;
8) 6 * QCN - .085 * QCN ^ 2 < 175 ;
9) 100 * QAE - 1.4595 * QAE ^ 2 < 200 ;
10) 50 * QBE - 1.2978 * QBE ^ 2 < 100 ;
11) 40 * QCE - .8395 * QCE ^ 2 < 200 ;

Separable cost constraints:

	Irrigation	Energy	Navigation
Cnty A	0	100	25
Cnty B	0	50	10
Cnty C	0	50	25

12) 8 * QAN - .211111 * QAN ^ 2 > 25 ;
13) 4 * QBN - .10625 * QBN ^ 2 > 10 ;
14) 6 * QCN - .085 * QCN ^ 2 > 25 ;
15) 100 * QAE - 1.4595 * QAE ^ 2 > 100 ;
16) 50 * QBE - 1.2978 * QBE ^ 2 > 50 ;
17) 40 * QCE - .8395 * QCE ^ 2 > 50 ;

Calculation of the optimal price:

18) 8 - .25124 * QAI = PAI ;
19) 4 - .2939 * QBI = PBI ;
20) 6 - QCI = PCI ;
21) 8 - .21111 * QAN = PAN ;
22) 4 - .10625 * QBN = PBN ;
23) 6 - .085 * QCN = PCN ;
24) 100 - 1.4595 * QAE = PAE ;
25) 50 - 1.2978 * QBE = PBE ;
26) 40 - .8395 * QCE = PCE ;

Calculation of the payments for each country and service:

27) PAI * QAI = RAI ;
28) PBI * QBI = RBI ;
29) PCI * QCI = RCI ;
30) RAI + RBI + RCI = PAYMENTI ;
31) PAN * QAN = RAN ;
32) PBN * QBN = RBN ;
33) PCN * QCN = RCN ;
34) RAN + RBN + RCN = PAYMENTN ;
35) PAE * QAE = RAE ;
36) PBE * QBE = RBE ;
37) PCE * QCE = RCE ;
38) RAE + RBE + RCE = PAYMENTE ;
39) PAYMENTI + PAYMENTE + PAYMENTN = PAYMENT ;

40) RAI + RAE + RAN = PAYMENTA
41) RBI + RBE + RBN = PAYMENTB ;
42) RCI + RCE + RCN = PAYMENTC

Contraints for separable costs of the services:

43) PAYMENTI > 30 ;
44) PAYMENTE > 300 ;
45) PAYMENTN > 150 ;

CALCULATION OF THE KEY:

46) PAYMENTA / PAYMENT = APART ;
47) PAYMENTB / PAYMENT = BPART ;
48) PAYMENTC / PAYMENT = CPART ;

SOLUTION :

VALUE OF THE OBJECTIVE FUNCTION

1) 367.892678

VARIABLE	VALUE	REDUCED COST
QAI	8.540899	.000000
QBI	35.000000	.000000
QCI	10.000000	.000000
QAN	29.535385	.000000
QBN	31.918211	.000000
QCN	53.259528	.000000
QAE	2.062059	.000000
QBE	2.116244	.000000
QCE	5.676202	.000000
PAYMENT	700.000000	.000000
PAI	5.854185	.000000
RAI	50.000000	.000000
PBI	.000000	13.856090
RBI	.000000	.000000
PCI	.000000	3.106321
RCI	.000000	.000000
PAYMENTI	50.000000	.000000
PAN	1.764785	.000000
RAN	52.123607	.176064
PBN	.608690	.000000
RBN	19.428295	.000000

PCN	1.472940	.000000
RCN	78.448098	.263647
PAYMENTN	150.000000	.000000
PAE	96.990425	.000000
RAE	200.000000	.000000
PBE	47.253539	.000000
RBE	100.000000	.000000
PCE	35.234828	.000000
RCE	200.000000	.000000
PAYMENTE	500.000000	.000000
PAYMENTA	302.123607	.000000
PAYMENTB	119.428295	.000000
PAYMENTC	278.448098	.000000

KEY IEP

APART	.431605	.000000
BPART	.170612	.000000
CPART	.397783	.000000

Note that at the "prices" generated, there is a substantial reduction of the quantities used for each service.

RETROACTIVITE

The following example of the application of retroactivity of the key uses the ASCRB method of allocation. The payments are based on 30 years at a rate of interest of 5%.

Country	Total allocated	Annual payment	Total paid after 30 yrs
A	269.54	17.534	526.02
B	156.10	10.155	304.64
C	274.36	17.848	535.42

TOTAL PAID TO CREDITORS: 45,537 per year or 1,366.11

After 10 years the total paid is:

Cnty A 175.34 (85.493 in interest)
Cnty B 101.55 (49.513 in interest)
Cnty C 178.48 (87.02 in interest)

Total 455.37 with 910.740 remaining to pay.

At the end of the first 10 years, a revision of the key is made, giving a new key:

Cnty A 45% or an annual payment of 20.491 (.45 x 45.537)
Cnty B 25% or an annual payment of 11.384
Cnty C 30% or an annual payment of 13.661

Without retroactivity, these payments would replace the preceding payments until the calculation of the next key. With retroactivity, the differences between the payments made and the new payments are calculated as follows:

Cnty A = 20.491 - 17.534 = 2.957 per year, or a total of 37.19 including the 5% interest.
Cnty B = 11.384 - 10.155 = 1.229 per year, or a total of 15.46 including interest.
Cnty C = 13.661 - 17.848 = -4.187 per year, or a total of -52.66 with interest.

Thus, Country A and B must pay to Country C the sum of the underpayment. It is probable that such a sum would not be available immediately, and the countries would have to make these payments over time with interest. For a 10 year term payment with 5%, Countries A and B will pay respectively 4.82 et 2.00 per year to Country C. Note that there is some encouragement for countries to slow their rate of development to gain cash flows. Further , the countries have no certainty that their initial payments will be adequate, and may have

to maintain a contingency fund.

At the end of the following five years, an major investment takes place in the project. The key is recalculated as follows:

Cnty A = 40% or a payment of 18.214 (.40 x 45.537);
Cnty B = 20% or a payment of 9.107;
Cnty C = 40% or a payment of 18.214.

For a single period of retroactivity:

Cnty A = (18.214 - 20.491) = -2.277 per year or -12.582;
Cnty B = (9.107 - 11.384) = -2.277 per yr or -12.582;
Cnty C = (18.214 - 13.661) = 4.554 per yr or 25.164.

Given the compensatory payment for the past 10 years, and the amounts due, the payments for the 5 years following (five years at 5% interest) for retroactivity are C to A, 2.906 per yr; C to B, 2.906 per yr. The net payments will be: A to C, 1.914 (4.81-2.906) per yr and C to B, 0.906 per yr (2.906-2.00).

If retroactivity is applied to the beginning of the project, the over and under payments for the first 10 years must also be calculated:

Cnty A = (18.214 - 17.534) = 0.68 or a total of 8.55 ; Also, the interest for the past five years will have to be paid, which makes the total for Cnty A of 10.91
Cnty B = (9.107 - 10.155) = -1.048 per yr or -16.82.
Cnty C = (18.214 - 17.848) = .366 per yr or 5.88.

However, the payments during the preceding 5 years must also be considered, because the sums which were not due were paid, as will as the interest. Thus, B has an over payment for the two periods, and his payments to C during the past 5 years must be recalculated and repaid with interest, resulting in about 29 untils that B owes as a result of the recalculation. C must also compensate A for its overpayment during the first compensatory payment by 37.19 plus interest.

Two problems have been demonstrated:

First, the uncertainty of the repayment of project costs is clear. The longer the period of retroactivity, the more uncertainty is associated with retroactivity. The necessity for each country to make provisions for these compensatory payments may require significant contingency funds.

Secondly, the accounting and cost of administrative will be significant. The longer the period of retroactivity, the more difficult and costly will be the accounting problem.

A third implicitly problem can also be seen: decreasing the rate of development, and with it the benefits to the project, does not mean that the repayments required for a given country will fall, since it is the relative change in benefits which matters.