

**economic analysis
of
forestry projects:
readings**

**policy and planning service
forestry department**

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FOREWARD

This volume of papers forms part of a series of publications that have been produced by the Planning and Investment Studies Unit of FAO's Forestry Department in order to make available information on analysis and planning in the forestry sector for teaching and reference use. The series, which has the title "Economic Analysis of Forestry Projects", consists of a guide to analysis¹ and a volume of case studies² in addition to the present volume of readings.

This volume of readings has been edited for FAO by H.M. Gregersen, Professor of Forestry and Agricultural and Applied Economics at the University of Minnesota. The coverage of the four papers is reviewed in his Editor's Introduction. All of them have been specially commissioned for this FAO series from the authors, each of whom is writing here in his personal capacity. The work on the two papers by authors at the University of Minnesota was made possible through a special budgetary contribution to FAO for this purpose from the Swedish International Development Authority (SIDA).

¹ Economic Analysis of Forestry Projects. FAO Forestry Paper No. 17, FAO, Rome, 1979.

² Economic Analysis of Forestry Projects: Case Studies. FAO Forestry Paper No. 17, Supp. 1, FAO, Rome, 1979.

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EDITOR'S INTRODUCTION

The present publication is provided as a complement to FAO's recently published guide, Economic Analysis of Forestry Projects^y, (henceforth referred to as EAFF), which deals mainly with the steps involved in organizing and carrying out an analysis of the economic efficiency associated with a forestry project. As mentioned in EAFF, economic efficiency is only one of the factors with which decision-makers are concerned in their quest to make "better" decisions concerning forestry projects. In addition, they may be concerned explicitly and quite separately with income distribution impacts, effects of projects on local areas as opposed to the nation as a whole, balance of payments or trade effects, employment implications, and so forth.

Both the McGaughey and Schuster papers in this volume deal with the question of income distribution and employment impacts of forestry projects — topics of increasing concern to decision-makers in developed as well as developing countries. While much of the recent discussion in the project analysis and evaluation literature has been concerned with the means to quantitatively incorporate income redistribution impacts directly with efficiency impacts in an integrated "social economic" analysis framework, both McGaughey and Schuster treat income redistribution impacts using a partial analysis approach such as suggested in EAFF. The idea of developing "weights" for costs and benefits associated with different income groups and introducing such in an economic efficiency analysis is appealing in theory and concept, but difficult to implement in practice, due to lack of agreement on specific weights to be assigned different groups. While labour shadow prices implicitly recognise the lower social cost (or higher social benefit) associated with using unemployed labour, McGaughey and Schuster both provide additional separate measures of employment and income distribution impacts which can be calculated and used in making additional comparisons between forestry projects.

McGaughey treats improved income distribution and increased employment as complementary goals in rural development projects. He discusses a number of different specific measures which can be calculated and used for various purposes in assessing project impacts on employment, regional income and income distribution. However, he concludes that: "What is clear is that no income distribution indicator can be universally recommended, since such indicators will have to be adapted in each country to the local data conditions and limitations which project analysts face."

Schuster discusses several different dimensions associated with income redistribution and employment impacts. He distinguishes between regional income redistribution and "individual welfare" impacts of projects. The impact indicators recommended for consideration in terms of individual welfare were selected on the basis of "their presumed relevancy and their feasibility to be measured". Based on this criterion, he chose project impact on 1) unemployment rates, 2) average wage rates, and 3) income distribution among the population of the region affected by the project. He further discusses measures of project effect on economic equilibrium and stability in local communities or regions, recognising that these two factors affect community welfare in a broader sense.

^y FAO Forestry Paper No. 17, FAO, Rome, 1979.

McGaughey deals at some length with various measures of project impact on foreign exchange flows (or balance of payments impacts), recognising that this is a factor of considerable importance to many decision-makers. Schuster, recognising the importance of regional distribution impacts of projects, discusses several useful measures of project impact on local government. He specifically looks at intergovernmental payments (revenue sharing, in-kind payments, and other types of payments) and discusses types of local government costs often associated with projects which are not considered in economic efficiency analyses. McGaughey also discusses appropriate measures of regional economic growth which can be calculated as part of a broader project analysis.

While Schuster in general sticks with impact measures related to single objectives, such as employment, income redistribution, regional stability, etc., McGuaghey goes on to discuss several multiple objective evaluation procedures which can be applied in practice. These include the Delphi method, scoring models and various means for combining single goal indicators. McGaughey further indicates the usefulness of sensitivity analysis in looking at project impacts and in providing information for decision-makers in cases where data are scarce or unreliable.¹

EAFFP provides a general approach to economic analysis of all types of forestry and forest industry projects. Peculiarities or unique aspects associated with specific types of projects, such as pulp and paper, or watershed and wildlife, are not discussed. The paper by Gregersen and Brooks in this volume deals with some of the specific problems and conditions encountered when analysing watershed projects.

The paper by Houghtaling and Gregersen provides a more detailed treatment of compounding and discounting procedures than is found in EAFFP. In addition, derivations of various useful compounding and discounting formulas are provided together with comments on how to treat some common time related problems encountered in project analysis - e.g. how to treat inflation and how to deal with situations where multiple discount and/or compound rates have to be used for a given analysis.

Finally, it should be pointed out that EAFFP and the present volume are limited to discussions concerning economic efficiency, income distribution, local area economic impacts, balance of payments and employment impacts - all items that in the broadest sense can be associated with various economic and social aspects of welfare. It is explicitly recognized that further work on treatment of impacts from an environmental point of view is needed. However, this is beyond the intended scope of the present effort.

¹ See also EAFFP, Chapter 10.

INVESTMENT CRITERIA FOR AGRICULTURAL AND RURAL DEVELOPMENT PROJECTS:

The Measurement of Their Multiple Economic and Social Consequences

by

Stephen E. McGaughey *y*

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1. INTRODUCTION

In recent years extensive improvements have been made in project evaluation methods in order to incorporate considerations beyond the traditional concern of project analysts with economic efficiency or profitability. Most of these improvements have been in the realm of more theoretically complete project evaluation systems. The most notable procedures include those developed by Little and Mirrlees (70) and Dasgupta, Marglin and Sen (117). Much of the later work has been an improvement and a refinement of this earlier seminal thinking.

The recommended methods are severely limited in many circumstances because (1) they are not designed to incorporate a large number of objectives; (2) a large data base is needed to complete the evaluation; (3) not much success has been achieved in simplifying the system for easy application by project analysts; and (4) little recognition has been given to the decision making process in developing countries which often proceeds in circumstances in which economic considerations may be of marginal importance.

The present paper is contributed in the view that while the investment decision making process is little known to economists, engineers and other project analysts, policy makers should welcome additional knowledge of the multiple economic and social consequences of the many projects that must be appraised in formulating an investment programme. While increasingly individual projects will be evaluated using social cost-benefit analysis, the procedures herein recommended are posited as an intermediate step between essentially what occurs now (little or no formal appraisal of multiple objectives) and the widespread use of social benefit-cost analysis (which may be possible some years from now). In this paper multiple benefits and costs are first introduced via single objective evaluation criteria permitting the ranking of projects for the separate goals. A large number of project performance indicators are reviewed, compared and evaluated for use under different situations.

Alternative procedures for ascertaining, estimating and combining multiple objectives for project ranking are discussed, such as scoring models and a more direct weighting scheme proposed by McGaughey and Thorbecke (75). Finally, procedures for completing relevant sensitivity analysis are developed including simple graphical techniques and a more detailed elasticity analysis.

All of the proposed procedures should be of primary interest to national and sector planners who need tools for defining sector-wide investment programmes. Among other sub-sectors, the present procedures are formulated for application in devising water resource programmes, sector forestry plans and regional rural development programmes.

2. THE NEED FOR MEASURABLE INVESTMENT CRITERIA

While economic and social project evaluation methodologies, as they are now proposed, may one day be widely employed by international leading agencies and national planning authorities, there are few prospects that this will occur on a large scale soon, either in countries or by international agencies, especially if it is required that aspects such as income redistribution effects are to be accounted for in the evaluations.^y

Less developed countries need evaluation techniques that can be uniformly applied throughout all subsectors at a low cost with minimal data demands, producing results which are reasonably understandable to policy makers.^z In most countries there is a distinct propensity to apply narrow financial and commercial criteria to project selection. An advantage in these criteria is that most policy makers understand the concept of the financial and commercial criteria to project selection. An advantage in these criteria is that most policy makers understand the concept of the financial rate of return. The economic evaluation is of prime interest to agencies with a broad national or sector-wide viewpoint. The national and sector planning authorities or the planning office of the development finance corporation all have an interest in allocating resources to high priority sectors based upon general economic and social goals stated in development plans; but, project evaluations are not of great interest to policy makers in their day-to-day activities because they are primarily concerned with the allocation of financial (budgetary) resources.

A second reason why the most complicated socio-economic project evaluation methods have not been quickly accepted by public authorities is that they place heavy demands on scarce technical talents. Thus, while many project practitioners without advanced economic training may understand the use of financial criteria, it is doubtful that they will understand the evaluation techniques proposed by Squire-van der Tak (120), Little-Mirrlees (70), or UNIDO (117). In developing countries, trained specialists are mainly in demand as managers or administrators. They are assigned to the execution of programmes and projects rather than to their ex-ante evaluation. While a social cost-benefit analysis may be needed for projects or programmes to be financed by external lending agencies, the assignment of local specialists to these projects often occurs only to ensure financing by the agencies, by presenting the required economic and financial evaluations.

Economists tend to take an egocentric stance in designing investment criteria, over-emphasizing the importance of economic considerations in the final project selection. It is clear that a broad spectrum of objectives - economic, social, political and historical - are all combined in the minds of policy makers who allocate public investment budgets on a project-by-project basis or as a part of a medium- to long-term investment programme. While financial investment criteria will continue to be the centerpiece of the analysis, appraisals which occasionally take into account shadow price adjustments will be undertaken for large investment projects destined for external finance. Hence, the new evaluation techniques will likely be applied on a piecemeal, project-by-project basis for some years to come and their full integration into national, sectoral or regional planning is not likely to occur for one or two decades.

^y It may be argued that international lending agencies have no right to set weights on consumption or income benefits received by groups within a particular society. (See D. Lal (62). The weights logically would have to be set by national authorities and consistently applied to all projects, either for external assistance or those to be financed exclusively by local resources. To the extent that evaluation techniques are not used similarly by all parties, their value would seem to be severely limited.

^z See R. Chambers (19) who forcefully argues that "simple is optimal".

What is needed now is a perception of a sequence of improvements in prevailing evaluation procedures. Project evaluation techniques should meet the following tests: they should be measurable with available data; they should be applicable to a wide variety of project investment categories; they should be consistent with rural development or agricultural sector programme analysis; they should provide rankings of individual investment projects; they should be understandable to most policy makers who review the sector or project plans; and, finally, they should take into account multiple economic and social objectives and, thus they should be amenable to a multidisciplinary approach to project analysis. With the present short supply of trained economists and the low quality of the basic statistical information, the Little-Mirrlees/UNIDO social cost-benefit analysis does not seem to meet many of these tests.

First, concerning measurability, it is clear that most current appraisals are conducted on the basis of expert judgements (educated guesses) of the values of many project technical and economic parameters. This will continue to occur in years to come because the prospects of obtaining an independent, reliable data base for the massive application of cost-benefit analysis do not seem good.^y Also, that which is possible for a single project is not always possible for a large number of projects. A set of decision criteria is required, either partial indicators or social cost-benefit ratios, which can be applied on the basis of expert judgements and little information on the regions where the projects are to be located. As cost, price, production and market information improves, social cost-benefit analysis may be viable in a larger number of circumstances.

Second, the decision criteria for rural development projects should be suitable to a wide variety of projects as well as economic and social sectors. Rural development projects generally contain a complicated mixture of sectors, subsectors, investments and annual expenditures;^z decision criteria that would permit an improvement in their design will have to be compatible with these diverse subsectors and sectors.

Third, it is necessary that the decision rules used for rural development projects be integrated into the regional and sector, agricultural and industrial planning processes. This means that the decision rules would permit policy makers to rank the rural development projects along with other national development alternatives. The sector and regional planning authorities should be able to incorporate the projects into the budgetary process and to understand their economic and social impacts to the greatest degree possible. Short of rather complicated general equilibrium or multi-level planning models (see the models developed for Mexico (86) and the Ivory Coast (33)), it is difficult to imagine that multiple objective social cost-benefit analysis will be integrated into sector and regional planning in the foreseeable future.

^y For example, physical yield data, farm costs of production, the effects of soil conservation schemes among others may not ever be amenable to estimation except on a pilot or experimental basis.

^z Two recent examples of complex rural development programmes and projects include the Mexican PIDER and the Colombian DRI.

Fourth, the proposed decision criteria must be used to establish the optimum project mix within regions or within regional development programmes, determining the distribution of investment funds among directly productive and productive support activities and social infrastructure. When there is abundant information and trained specialists, programming models may be used for this purpose. The knowledge provided through social cost-benefit analysis of multiple objective effects will be extremely limited in most circumstances.

Fifth, the decision criteria should be useful to a multidisciplinary team of project designers and planners, allowing for the participation of all disciplines - economic, social, financial and technical - in the design and organization of the project. An evaluation technique that is the sole purview of a limited group of technicians, such as economists, will not likely receive the support needed to be adapted to a large number of project appraisals.

Six, an essential characteristic of the decision criteria is that they are understandable to policy makers who make the final investment and expenditure decisions. While much time and effort has been given to the simplification of evaluation techniques, they are still a mystery to most policy makers. Concepts such as shadow prices, conversion factors, the accounting rate of interest, and the consumption rate of interest are not familiar to most of them.

Finally, it is essential that decision criteria be applied with the understanding that a gradual improvement in evaluation techniques will be made; techniques which are useful during the next decade will be replaced, on a larger scale, by more sophisticated social cost-benefit analyses. A possible sequence of improvements might be the following: begin with current methods (which are, primarily, financial evaluations with added elements of an economic evaluation); gradually improve the economic evaluation for single projects, particularly, large scale projects which place major demands on the public budget; introduce simple indicators for the planning and evaluation of projects for multiple objectives and multiple sectors; adopt simple programming techniques such as goal programming to project and sector analysis; apply the complete social cost-benefit analysis to more sectors and to more projects; and, finally, undertake full scale social cost-benefit analysis and general equilibrium multi-level programming by sectors and regions. There are evaluation techniques suitable to each of these stages. However, the pre-conditions needed to apply them all are not extant. Decision criteria are needed which apply to rural development projects having multiple objectives.

The current challenge in most developing countries is to apply appraisals without great budgetary cost and using presently available data. The economist should take a more modest stance. Rather than pushing for the application of optimal investment criteria, he could provide a greater service by developing techniques which can be used without large changes in today's public agency staffs and budgets.

3. ALTERNATIVE ISSUES IN CHOOSING INVESTMENT CRITERIA

3.1 The Main Issues

The purpose of the present section is to examine the use to which investment criteria will be assigned in the evaluation of rural development projects. This use derives from the issues which have been mentioned relating to the ultimate purposes of rural development projects. The form that the analysis takes will depend upon the following principal contrasting elements: (1) financial versus economic analysis; (2) the measurement of multiple objectives and their weights versus single objectives; (3) constraints on the analysis, particularly institutional constraints versus unconstrained cases; (4) design versus project ranking, and (5) project versus regional programme planning.

3.2 Financial versus Economic Analysis *y*

In traditional cost-benefit analysis practitioners tended to rigidly separate financial and economic analyses. The former, among other things, is concerned with the commercial profitability of a project, while the latter is germane to improving the allocation of resources. As a consequence of incorporating income distribution and equity considerations into social cost-benefit analysis, a linkage between financial and economic analysis is made. Thus, the financial analysis, which treats the distribution of payments and repayments, and sources and applications of funds, is the major tool for tracing the incidence of benefits and costs of a particular project; financial analysis is now more important than a mere indicator of the capacity of the project beneficiaries to repay loans. This is especially crucial to the design of rural development projects.

3.3 Multiple Objectives

One of the perplexing problems in economic and financial analysis is how to systematically introduce multiple goals into project design. This problem has been broadly examined by Norton, Bassoco, and Silos (86), Sfeir-Younis and Bromley (106), Papandrea and Zohar (89), and McGaughey and Thorbecke (75, 76). Other specific applications of multiple objective analysis are discussed later in relation to specific investment criteria.

Multiple objectives may be introduced in several ways. One way is to specify explicitly the separate partial impacts of projects on one or another economic and social objective. The purpose of this approach is to emphasize the individual effects of a project without combining them into a single measure. As long as decision making is limited to a few projects, regions and objectives, mathematical programming models may be an appropriate technique for introducing multiple objectives and selecting priorities, but the number of circumstances in which the models can be applied seems rather limited, especially if the main purpose is to design a comprehensive (national) rural development programme.

y This issue is treated in *Economic Analysis of Forestry Projects*, FAO Forestry Paper No. 17.

In addition to the problem of how to combine multiple economic objectives, regions and projects in a consistent fashion, a further complication is how to set welfare or preference weights on these objectives. This is, if a policy-maker can identify, for example, four objectives, it is clear that he might not place equal importance on all of the objectives. It is more likely that greater weight might be placed on one or two principal objectives, assigning less significance (or weight) to "secondary" objectives.

In later sections an effort is made to design simple systems to incorporate multiple objective weights into the evaluation and design of rural development projects. Four economic objectives are considered: (1) an increase in production and income in rural areas; (2) an increase in remunerative employment and an improvement in the income distribution; (3) the attainment of an improved regional balance in growth and development; and (4) an increase in foreign exchange earnings.

An increase in income, consumption and value added - one of the most important objectives of economic analysis - is referred to as the economic efficiency objective. If projects are chosen solely on the basis of the efficiency goal, there is no guarantee that beneficiaries of the investment programme will represent the lowest income groups. Indeed, if one were to select projects only on the basis of the efficiency goal then commercial agricultural producers with access to financial resources and other assets often would be the main beneficiaries. Usually, rural development projects are designed with a particular beneficiary group in mind, so the "second-best" efficiency objective is to maximize the net benefits of the beneficiary group within a certain project area. However, planners may be disappointed to find that the opportunity costs associated with investments for increasing the benefits to smallholders and other poor rural inhabitants may be high.

The goal of increasing the amount of remunerative employment from the project investments is closely related to the income redistribution effect. This goal is so much akin to the income redistribution goal that several authors, including Marglin (80), have argued that the employment objective is a surrogate for the income redistribution goal. They emphasize that employment is not desired for its own sake, but rather as a vehicle for increasing income and welfare.

Various dimensions of the problem will have to be considered to introduce employment indicators. A distinction must be made between permanent and seasonal agricultural and non-agricultural, high-paid and low-paid employment, and the preferences of policy-makers for employment creation at different points in time. These differences are not always directly disaggregated in social cost-benefit analyses since equity considerations are introduced in the form of welfare weights on the benefits and costs of the low income beneficiaries. Therefore, one advantage of using partial indicators of project performance is that these qualitative features of employment can be explicitly enumerated.

Rather than taking employment as a substitute measure of income redistribution effects, an alternative is to take the direct effects of a project on the prevailing regional income distribution. Procedures for treating income distribution consequences have been fully discussed by, among others, Balassa (5), Byerlee (16), Harberger (39), Kalter and Stevens (61), Little and Mirrlees (70), UNIDO (117).

The promotion of regional economic balance is another important economic objective, i.e. promoting backward regions relative to regions which have attained acceptable levels of per capita income. This difference is more than the mere distinction between promoting development in rural as opposed to urban areas. There may be urban areas in backward regions which have an important role to play in the income growth of the poorest income groups in surrounding rural areas. Three major policy questions dominate the issue of regional economic balance. First, there is the desire on the part of national authorities to achieve greater diversification to improve the terms of trade between agriculture and industry, from one region to another. Secondly, the government may want to change the regional location of an activity, particularly rural development activities; direct or indirect government influence can be used to achieve a desired locational mix of rural development activities. Thirdly, allocations might be made among regions to maximize the opportunities for further long-term growth.

Improving the balance of payments is one of the most widely propounded economic objectives in less developed countries. It is also a goal which is extremely difficult to interpret at the project level especially when considering single projects. The objective might be stated in terms of maximizing the net foreign exchange benefits of a project, increasing the exports of specific items or substituting the imports of others. Such objectives are introduced in project evaluation via the introduction of a foreign exchange shadow price.

3.4 Institutional and Related Concerns

Project appraisal must proceed under a gamut of constraints which limit the scope and ultimate effectiveness of a project both for the executing agencies and the beneficiaries. To the extent possible, project appraisal methodologies should help identify and quantify these constraints, to determine the consequences of eliminating the most important ones. The task becomes more complex for rural development projects in which there are constraints which, in effect, cut across many subsectors in several regions. Likewise, there are constraints which are national in scope not originating in a particular region or sector which may alter the ambiance in which the project functions. These constraints can be divided into (1) financial, (2) human and manpower, (3) institutional and administrative, and (4) social categories. This categorization is not a complete one.

Financial constraints refer to limits on the availability of funds for project fixed and working capital and operating expenditures. The national treasury limits the amount of funds which go to the various ministries while sector (e.g. education, transportation, health) allocations limit what might be available to a particular rural development project or region. Without a national political decision there is little that can be done to alter these national financial constraints. At the regional and local level, project authorities may have greater access to funds such that, for example, crop and livestock lending at the local level can be redirected to the beneficiaries of an indicated rural development project. These possibilities will depend upon the circumstances prevailing in each country where rural development projects are being executed. It is important in project evaluation that the type of funds constraining project execution be determined. But little can be done by project authorities to change fundamental constraints although the purpose of designing rural development projects per se is to coordinate the assignment of public funds for specific projects within specific regions where such coordination did not occur before.

Financial constraints are accounted for in project appraisal through the conventional flow-of-funds analysis and by an analysis of the incidence of expenditures on beneficiary groups within the economy. Thus, certain beneficiaries may be required to repay relatively more than others so that the allocation of project funds will have differential effects on the beneficiaries' income distribution.

A second fundamental project constraint relates to the availability of trained specialists and other manpower categories for project execution. When such human resources are not available, a training programme must be undertaken with the cost generally attributed to the project. Start-up and execution time for the project will likely be lengthened. Or if the project draws trained manpower away from other activities, then extraordinary funds may have to be assigned to pay these specialists at wage rates that are sufficiently attractive for them to make the changes. Rural development projects involve redirecting the use of existing public sector specialists to the new projects as well as requiring additional numbers of specialists because of the overall increase in project activity and financing. Such manpower constraints will have to be incorporated into the project cost estimates and specific indicators of project labour use will have to be obtained in order to compare rural development project needs.

Institutional problems are the most pervasive and abstruse project constraints as well as the most difficult to alleviate. They take so many forms that the category - institutional constraints - is probably too extensive. Rather sub-categories including structural features, personnel management, financial management, technical management, and overall administration procedures have to be considered to fully define the nature of the institutional problem.

Structural problems refer to whether the institutional framework is compatible with the project design and objectives (obviously, project design and objectives have to be adjusted to the institutional structure as well, but here we are concerned with the obverse of this proposition). If a project involves the active participation of local beneficiaries in its design and execution, it is likely that the decentralization of public services will have to be undertaken to be consistent with this kind of project organization. Likewise, if a particular basic service is supplied by several competing offices, then it might be necessary to consolidate their functions under a single responsible agency. The decentralization of government activities can in itself add to costs and this will have to be balanced with the expected benefits.

Personnel management which improves the utilization of the skills of all agency and project employees is needed for successful project implementation. Personnel standards are often different among the several agencies involved in the execution of a rural development programme and they may have to compete for staff because of different salary levels among the agencies or because of staff dissatisfaction from similarly qualified professionals being paid different salaries for the same work requirements.

Financial management and administration is crucial to the smooth functioning of a project to ensure that materials and operating supplies are provided at the location and at the rate which is concomitant with staff execution capacity. Information on the length of the production cycles and operating funds demands are the basis for the estimates of the requirements for working capital and other financial resources. Indicators of the efficiency of the internal use of the financial funds and the viability of funds management should be obtained.

The technical staff of an institution needs extra guidance as new projects, such as rural development projects, are initiated. The staff may be unaccustomed to work with the new beneficiary groups and also may not be familiar with sharing project design and execution control. This situation requires special skill, tact and understanding on the part of the technical managers. When project staff have to be geographically shifted or when their functions radically change because of the introduction of a new project, then these changes should be quantified.

The administrative procedures which bear on whether a project is successful or not are not easily identified. Whether internal administrative coordination among major subdivisions takes place has a direct bearing on the coordination of the separate projects components. It is clear that one cannot quantify such relationships and only with a long historical perspective on the performance of the agency in a region can one see where the improvements must be made.

Institutional weakness tends to be used as a catchall category referring to a large number of problems endemic to most newly evolving agencies, including social, political and economic problems. While it may be easy to prescribe internal administrative improvements, they will only take place gradually over a long period in which staff is trained and new relationships established. Project evaluators must look to the internal capacity of agencies before introducing complex procedures which take up the time and resources of these agencies.

Social constraints refer to those broad classes of problems deriving from historical, cultural, behavioral and anthropological features of a society which affect the anticipated outcome of the project. Production systems, operating procedures, incentive and control mechanisms must all be adjusted to the presence of such fundamental constraints. While quantitative project evaluations provide little direct information on these features, it is essential that sociological studies be undertaken before the basic project benefit and cost flows can be constructed, because such flows subsume the economic and social system. The need to understand the social dynamics of an investment project is especially important for rural development projects in which contact with the rural poor is being made on a scale previously unknown to public agencies.

3.5 Designing and Ranking

While the recommended way to evaluate and select a project is to apply a single criterion to its simultaneous designing and ranking, in practice, this often does not occur. Separate agencies are responsible for the two activities - designing and ranking - and a considerable period of time, even years, may divide the period in which these choices are made. The designing of a project concerns the choice of its size (e.g. height of a dam, length of a canal, number of beneficiaries, volume of waste treatment, volume of potable water) and location within a region or district, as well as the timing of investments and the choice of technology. The ranking of a project involves a comparison between one project and another within a particular set of economic, political and social constraints so as to make a "go, no-go" decision to determine the time sequence in which the project might be executed compared to other projects in the list.

Project design is primarily a micro-oriented activity which relates technical, economic and social feasibility to determine a project's eventual characteristics. Local beneficiaries may participate in the design process in rural development projects or the basic project parameters may be handed down by a regional or national planning group. Simple criteria are needed which allow for the comparison of project benefits and costs at an early stage, well before detailed information of a project's cost and benefit flows are known. Thus, the final features of a project are often set very early during the long process of design, selection and execution.

The second problem is to rank a project within a comprehensive basket of project alternatives. Such ranking is often done at the national level and less frequently at a regional level by multisectoral planning groups, finance ministry or development corporation. While national development plans have evolved in many countries, there are few cases in which social cost-benefit analysis has been employed to rank a large number of projects. This occurs because, while for a single project there may be adequate detailed data to apply the complete social cost-benefit analysis, there may be limited data for several other projects. The most complex methods are effectively neutralized by only one important project within the set which has less than a complete data base. Therefore, simplified investment criteria are needed to compare projects even at a more advanced state of design and preparation. Likewise, a large number of projects are often not available to rank at any moment in time since projects are considered by planning authorities as they are identified and studied.

3.6 Project and Regional Development Planning

Investment criteria should be constructed as aids for regional and local economic and social planning. Present day criteria are especially accommodated to national planning needs in countries where local and regional planning is still in an incipient stage. But because of growing interest in rural development projects, which increase local participation in social and economic planning, simplified and measurable investment criteria are also a requisite for local and regional planners. While certain objectives such as income distribution improvements and economic growth have their equivalents at the regional level, methodological problems may be more severe at this level because of the limited data base as well as the diverse viewpoints of local planners. Usually, objectives such as increasing foreign exchange earnings are of secondary interest to local planners who are mainly concerned with many factors which affect local beneficiary groups. Hence, while if a preference weighting scheme reflects national goals, it is probable that the preference weights of local policy makers might be substantially different, even in the rather unlikely case in which these two groups of policy makers are concerned with the same objectives. National planners may be able to impose their preferences on the control of a large share of the regional and local government's revenues.

It is difficult to balance the two desirable features of simplicity and comprehensiveness in the same evaluation techniques and satisfy the needs of local rural development planners. At the local level techniques should capture the essence of the local social, economic and political aspirations, providing clear indicators of project performance that are relevant to local problems. Local notions of equity, income growth, preferred beneficiary groups and desirable product lines and employment activities should all be measurable by the available investment criteria. Furthermore, the concept of national economic parameters (33) (e.g. shadow exchange rates and interest rates) may have to be reviewed in light of the increasing importance of regional and local planning activities.

The separate viewpoints of national, regional and local public authorities should be explicitly introduced into project analysis because of their different perceptions of project benefits and costs. A benefit to a national planner (e.g. greater national employment) may be viewed as irrelevant to a regional project planner (because the employment does not fall within his region) or viewed as a cost (if revenues in the regional plan are used to pay for the employment generating activities). In the same example, elsewhere, a local municipality may have to incur local health and other social infrastructure expenditures because of the new residents attracted by the new investment opportunities. Hence, what is a cost (benefit) to one group may be a benefit (cost) to another. Project planners will, therefore, have to use great care in defining project net benefit flows in terms of specific points of view.

4. SINGLE OBJECTIVE MEASURES *y 3*

4.1 The Objective

The principal economic objectives associated with national and sectoral level planning generally include (1) the income or efficiency objective, (2) the employment and income distribution objective, (3) the foreign exchange earnings objective and (4) the regional growth objective. Other objectives such as price stability, properly pursued by monetary and fiscal policies, are not considered in project appraisal. While a project may contribute to price instability, there is no way this effect can be measured using present economic techniques. Rural development projects are specifically attuned to promoting national income growth and redistribution as well as correcting strong regional imbalances in per capita income and social services. The goal of increasing foreign exchange earnings may enter the choice of projects activities even though a rural development project may not have strong, positive balance of payments effects.

y This and later sections are substantially based on approaches presented in McGaughey and Thorbecke (75), as well as Papandreou and Zohar (89).

3 Project evaluation criteria have been thoroughly considered by project practitioners. This topic is covered in a variety of books, manuals and articles on the subject including economic and financial writers, especially in FAO's Economic Analysis of Forestry Projects and books by Gittinger (32), Little-Mirrlees (70), UNIDO (117), and Roemer and Stern (96). The three criterion are: (1) the discounted present value criterion; (2) the benefit-cost ratio (a version of the present value criterion); and (3) the internal rate of return. They permit a comparison of the net benefit flows of alternative projects (or designs) by incorporating the comparison of net benefits received at different points of time.

It is recommended here that a version of the present value criterion such as the benefit-cost ratio be used in ranking rural or agricultural development projects. This seems most appropriate for the design of rural development projects, especially if there is a large number of alternatives that have to be ranked, a severe budget constraint, project components are from greatly varying economic subsectors, and if many of the component parts are likely to be fairly divisible.

In the following sections each of the distinct economic and social objectives will be considered and individual indicators will be constructed which measure the effects of individual projects. The single objective criterion for each will be developed on the assumption that practitioners may confront a wide variety of circumstances in which data are severely limited at the early stage of project design. For later refined feasibility analysis it can be expected that the economic and social data will be more abundant and, consequently, more complex investment criteria may be applied to measure simultaneously the impacts of the projects on the several social and economic objectives.

4.2 The Income (Efficiency) Objective

This objective is to maximize the income or consumption contribution of the project to the economy. The objective may be measured on the basis of present value criterion using shadow prices. The total benefits of a project are the real income flows received by the beneficiaries. Thus, a rural development project has directly productive activities which result in increases in net farm incomes, increases in incomes to those providing market or agricultural credit services and indirect increases in incomes from rural education, health or other social services. It is exceedingly difficult to estimate the long-term income effects of a rural education programme. If these net income flows can be estimated, then they belong as a part of the total benefit flows of the project.

First, determine whether the project is feasible given an interest rate for computing the present discounted value of the net income benefits of the project. Secondly, follow the standard procedures outlined in the project evaluation manuals. If the project has a net positive present value or if its internal rate of return exceeds the opportunity costs of funds reflecting the capital constraint, then the project can be considered feasible in terms of the income objective. It is recommended here that some value criteria should be applied on a trial and error basis. For the purpose of ranking project alternatives it is recommended that the net benefit-cost ratio be applied to rural development projects. Depending upon the circumstances of available data or the detail of the required project design, four alternative forms of the benefit cost-ratio can be used to rank projects in terms of the national income objective. These are: ^y

$$\frac{X}{I} = \frac{PV_i (X_t)}{PV_i (I_t)} \quad (1)$$

$$\frac{V}{I} = \frac{PV_i (X_t - O_t)}{PV_i (I_t)} \quad (2)$$

$$\frac{B}{C} = \frac{PV_i (X_t - C_t)}{PV_i (I_t)} \quad (3)$$

$$SMP = \frac{PV_i (V_t - D)}{PV_i (I_t)} + s \frac{PV_i (F_t)}{PV_i (I_t)} \quad \text{and} \quad (4a)$$

$$PV_1 (F_t) = PV_i (B_1 + B_2 + B_3) \quad (4b)$$

^y $PV_i(X)$ means the sum of the present discounted values of gross production X , each year t , at interest rate i .

Terms are defined:

X_t = gross production, year t ;

I_t = fixed investments, year t ;

C_t = operating costs, year t ;

V_t = domestic value added, year t ;

D_t = domestic operating costs, year t ;

O_t = purchased inputs other than labour and land, year t ;

F_t = net foreign exchange effects, year t ; and

s = the ratio of the difference between the shadow and official exchange rate to the official exchange rate.

The ratio shown in equation (1) is the output-capital ratio - the value of the gross production in each year X_t and the fixed investment outlays in each year t , I_t , discounted at rate i . This ratio is appropriate only when little project information is available. It may even occur that project practitioners will have to employ an undiscounted version of this ratio in the preliminary selection of project designs. While one can agree that this ratio is not justified under most circumstances because it excludes project costs, it may occur that due to lack of farm budgets and other basic cost data, analysts would be forced to rely upon this simple output-capital ratio.

A second indicator of the income objective is the ratio of project value added to investment expenditures. This relationship is shown in equation (2) as the ratio of the present discounted value of gross production less purchases to the present value of the project investments. This ratio measures the direct contribution per dollar of investment expenditure in the project. Shadow prices should be included if they are available.

It can be expected that the shadow prices will not easily be obtained. If the national or sector planning authorities have supplied shadow prices to the project analysts then, of course, they can proceed to undertake a more complete cost-benefit analysis as shown in equation (3), if all project cost and benefit components are known. This is the well known ratio of the present value of net benefits of a project to the present value of the capital expenditures including adjustments for the shadow prices of foreign exchange and labour, as well as the social opportunity cost of capital. The ratio may be used to obtain a ranking of investment projects according to the income objective. y

y The preferred form of the benefit-cost ratio is the "net" ratio; in the numerator are the net variable benefits accruing to beneficiaries during the project's operation and the denominator contains all fixed cost entering the budget constraint including all initial investments.

A form that may be used to analyse the income or efficiency contribution of a project is the Social Marginal Productivity criterion (SMP) introduced nearly twenty years ago by Chenery (20). The criterion, while similar to the benefit-cost ratio, separates the balance of payments effect of the project from the domestic value added-investment ratio. The SMP is defined as the ratio of the domestic value added to the capital expenditure plus the balance of payments effect per dollar of investment expenditure adjusted by an appropriate shadow exchange rate. The balance of payments effect (F) is made up of three elements which include, B_1 , the indirect and direct effects of the investment expenditures, B_2 , the direct effects of the project's operation and B_3 , the indirect operating impact of the project.

4.3 Employment and Income Distribution Objectives

The objectives of increased employment and an improved income distribution may be treated separately or as complementary goals. While it is possible to conceive of circumstances in which the two objectives are at odds, - e.g. that greater employment may produce a more unequal income distribution or an improved income distribution may result from less employment - it is assumed here that employment and the income distribution are complementary goals. Thus, the creation of greater employment in rural areas would lead to an improved income distribution and in circumstances in which the precise regional income distribution is not known, it is possible to use an employment performance indicator as a substitute for the income distribution indicator. Since rural development projects are designed to benefit the low income sector then greater employment and income in this sector will, paripassu, produce an improved regional income distribution. The employment or income distribution indicator should be a ratio of employment or income distribution improvements to the initial capital expenditures or other relevant financial constraints.

Initiating the discussion with the employment objective (a surrogate of the income distribution objective), several considerations must be kept in mind in applying employment creation indicators for the purposes of ranking rural development projects. First, consideration should be given to separating employment into that produced during the initial stage in which the infrastructure and other facilities are being installed; this employment can be thought of as temporary compared to the employment generated during the project's operating phase. This does not mean that public works employment is undesirable, rather that as the public works are completed within a region, the volume of this type of employment declines rapidly. It is possible that unskilled, semi-skilled and skilled workers employed on the construction may be able to obtain other employment once the irrigation projects and marketing facilities, research facilities, and educational programmes are underway. But it also may occur that construction workers will not be able to obtain permanent employment, except for a few agricultural labourers who participated during the construction of the infrastructure.

Where:

L^O = employment of skilled and semi-skilled (poor) workers during the operating phase.

L^C = employment during the construction phase.

I_t = the total fixed investment outlay.

X_t = the gross output of the project.

Another appropriate measure substituting for output might be project value added of other indicators such as net project income. The employment generated by the project should be discounted at an interest rate which reflects the urgency or the impatience (time preference) of public authorities in creating employment at different points in time. It may be that the interest rate applied to the employment ratio will be higher (lower) than the interest rate applied to the discounting of the consumption flows of the project depending upon the rate of time preference for these benefits, although Lal (63) argues that they should be equal.

It is necessary to separate the employment created during the operating phase from the employment generated during the construction phase since they will involve different technological choices affecting the labour intensity of the project. It is also clear that the direct labour-capital ratio does not take into account the indirect employment generated in a region from a rural development project; in order to estimate the indirect employment impacts of a project, input-output tables and employment multipliers may be used to trace first, second, third, and fourth round employment effects within a region. If the input-output table is available the labour-capital ratio of equation (5) could be expanded to include a third element in the numerator - the present value of the net indirect employment created. The labour-capital ratio is simply interpreted: a project with a larger labour-capital ratio is more desirable to public authorities than one with a smaller ratio. Accordingly, when comparing projects that produce similar outputs, with similar capital expenditures, then a labour-output ratio as shown in equation (8) would be appropriate for a comparison of project investments.

In a study of irrigation projects McGaughey and Thorbecke (75) found that the bulk of employment created by the projects occurred during the operating phase and the employment created during the construction phase was around one-third of the employment obtained during the operating phase. It is not difficult to imagine that, through experience, project planners will be able to establish a rather definite idea as to what the employment-capital ratios are likely to be for different types of projects using alternative technologies, making it possible during the design phase, to eliminate projects which are grossly inferior in their generation of employment opportunities for unskilled, poor labourers.

$$PRI = \frac{(N^O + N^C)}{(rI + C)} \quad (9)$$

The poverty redressal index (PRI) of equation (9), proposed by Lal (63), is an annual employment/project cost ratio showing the number of poor people employed by a project during the construction (N^C) and operating (N^O) phases per dollar of project costs, consisting of the equivalent annual investment and depreciation costs (rI) plus the equal annual variable operating costs (C). The initial investment, I , is converted into an annual equivalent by the factor r , which reflects the social rate of return to investments and the annual capital maintenance and replacement costs; the initial employment contribution is also transformed into an annual equivalent by the time preference rate i , for present and future consumption. The larger the ratio PRI the more people benefit from a project, hence a project which provides a larger number of employment positions for the same or larger wage and investment bill is preferred to a project which provides few employment slots at a smaller wage and investment bill.

If there are data on the size distribution of income by regional and national level, it may be possible to adopt more direct measures of the effect of investments on the distribution of income. The most direct approach is that used by Kalter and Stevens (61) who trace the distribution of project costs and benefits to each individual income class within the region and show the net redistribution benefits of each income class, as the difference between the direct benefit that is received from the project and the direct and indirect outlays that the different income classes are required to make in reimbursing the project costs, directly and through taxes. Other measures of income distribution can be used for the appropriate project rankings and comparisons. Szal and Robinson (112) have surveyed the available income distribution measures. Of those reviewed, the ones that seem most appropriate for the evaluation of rural development projects include the following: (1) the Gini coefficient; (2) the (so-called) Population in Relative Poverty index defined as the percentage of the population having less than one-half of the median income; (3) the Maximum Equilization Percentage defined as the share of aggregate income that needs to be redistributed to the lowest income groups in order for the distribution of income to be perfectly equal or, alternatively, the proportion of total income that must be transferred from those above either the mean income or the poverty income in order for those below the poverty level to have their income increased to a level equal to the poverty cut-off level; (4) inequality indexes which relate the mean income of those who have less than the national mean income and the mean income of those who have more than the national mean income; and (5) indicators of regional beneficiary income expressed as a share of the total regional income or the region's income accruing to the rural poor compared to a national average income. If there is detailed knowledge of the size distribution of family, regional and national income before the initiation of a rural development project, then it would be possible to indicate the extent to which any of these proposed indicators change consequent to the project investments. ^{1/}

^{1/} It must be clearly admitted that detailed income distribution information is usually not available although this situation may be gradually improving in some countries.

Each of the individual income inequality measures will be considered in turn. First, the Gini coefficient falls between zero when the income distribution is perfectly equal and a value of one when the distribution is perfectly unequal.^y Therefore, an appropriate measure of the impact of the project on regional or national income distribution is the proportional reduction in the Gini coefficient per dollar of investment in the rural development project. Projects which effect a larger proportional reduction in the Gini coefficient would be considered more desirable than projects that make an incrementally smaller reduction in the Gini coefficient per dollar of investment outlay. Unfortunately, a weakness of this measure is that the Gini coefficient can be shown (see Szal and Robinson [112]) to be equal for several possible income distributions, allowing a shift in the distribution without changing the numerical value of the Gini coefficient itself. Likewise, Paglin (88) has shown the inadequacy of the traditional Lorenz curve in reflecting a reasonable concept of "equality".

Regarding the Population in Relative Poverty index (PRP) an appropriate project indicator could be the reduction in the percentage of the population which has less than one-half of the national median income per dollar of project outlay. For the Maximum Equalization Percentage, if the share of aggregate income needed to be redistributed to make the income distribution perfectly equal (or to provide the lowest income with an income equal to the average), is reduced by the project, then it can be argued that a net improvement in the income distribution has occurred. Consequently, the appropriate indicator would be the reduction in the share of aggregate income redistributed per dollar of expenditure on the rural development program or project.

Another alternative is to utilise the inequality indexes which relate the average income of individuals above the national mean and below the national mean income. Three measures, Y_p the average income of individuals below the national mean (\bar{Y}), and Y_s the average income of individuals above the national mean, can be related in the following fashion:

$$u = \frac{\bar{Y} - \bar{Y}_p}{\bar{Y}} \quad \text{and} \quad (10)$$

$$w = \frac{\bar{Y}_s - \bar{Y}}{\bar{Y}_s} \quad (11)$$

$$\text{PID} = \frac{w_o - w_t}{w_o} \quad / \quad (I) \quad (12)$$

^y See Szal and Robinson (112) for a definition of the Gini coefficient.

Equation (10) shows a relationship between the national mean and the mean income of people who are below the national mean; this index ranges from $u = 0$ when the national mean and the below-national mean incomes are equal, to a value of $u = 1$ when there is perfect inequality. Similarly, one can relate the average income of those above the national mean (\bar{Y}_s) to those below the national mean by index w which ranges from a value of $w = 0$ for perfect equality to $w = 1$ when there is perfect inequality. It is suggested that an approach might be to compare the indexes in a region before and after the development project and a ranking found by showing the percentage reduction in the values of the coefficients u and w per dollar of total outlay on the respective project or the per beneficiary dollar expenditure in the respective regions.

Table 2 shows the inequality indexes of equations 11 and 12 for two regions A and B in the year zero before the project begins and the year five after the first stage of the project terminates. Region A has the lowest per capita income of 100 compared to region B with a per capita income of 200 at the beginning of the period. Over the five-year period the average income in region A increased 20 percent while the average income of the "above-average" income groups (s) increased by nearly 7 percent and the income of the below-average groups (p) increased by 60 percent. In region B the income of all groups is higher than region A. The inequality indexes declined, correspondingly, by 11 and 10 percent in region A and 20.0 and 15 percent in region B indicating, thereby, that the increase in incomes and the reduction in inequality was more substantial in region B than in region A.

This illustrates a conflict in policy making that may occur in selecting rural development regional priorities in situations such as between A and B in the illustration. Region A is clearly worse off than region B, having a lower per capita income for all income groups in years before and after the project investments. However, the incomes in region B, especially of the lower income groups, rose much more than in region A. Therefore, if the resource costs of increasing the incomes in region A and B are the same, the index of performance, a ratio between the reduction in the inequality measures per dollar of expenditure, would have given preference to investment in region B.

Thus, policy makers may have to decide on a less proportional reduction in inequality by initially concentrating activities in the lowest income regions. This is a "merit want" of the kind referred to by Marglin (80) which derives from underlying political priorities that go beyond the simple application of economic investment criteria. A part of this conflict may be resolved by using a general indicator of project performance as shown in equation (12). This inequality index is defined as a ratio between the percentage reduction in inequality as measured by the inequality index before and after the project investments, to the per capita investment outlays (I) during the project's life. This Project Income Distribution index (PID) is posited as a direct measure of project performance that corrects for regional population sizes and public expenditures that might be more cost-effective in one region compared to another. For example, assuming that region A (Table 2) has a population of 500 000 and region B a population of 250 000 and each project has a total cost (I) of US\$50 million; the per capita outlays to raise the regional incomes from year 0 to year 5 are, respectively, US\$100 in region A and US\$200 in region B.

Table 2. Project Inequality Indices and Regional Ranking

Region or Project Area		Year 0	Year 5	Percent
<u>A</u>	\bar{Y}	100	120	20
	\bar{Y}_s	150	160	7
	\bar{Y}_p	25	40	60
	u	0.75	0.67	-11
	w	0.83	0.75	-10
	PID*	-	-	100
<u>B</u>	\bar{Y}	200	250	25
	\bar{Y}_s	385	390	1
	\bar{Y}_p	50	100	100
	u	0.75	0.60	-20
	w	0.87	0.74	-15
	PID*	-	-	75

Notation: See discussion in text of equation (10), (11) and (12)

* converted to an index with a maximum of 100.

The reduction in the inequality index w in the two regions provides a PID of 100 in region A and 75 in region B. This shows that a project located in region A which gives rise to increases in income within the region is preferred to region B where fewer higher income beneficiaries are found. The PID index is an example of the kind that might be constructed by national and regional planners to produce a project ranking on the basis of their impact upon income inequality within the beneficiary regions. It is evident that income distribution data often are not available for region or project areas, making it necessary to recur to direct measures of the cost-effectiveness of projects in increasing incomes of lower income groups, including the employment-investment ratios referred to in the previous section.

Finally, a statistic for regional income comparisons is the ratio of average regional income to average national income or regional income inequalities to national income inequalities. Table 3 shows two such simple indicators: namely, the ratio of the average regional income (\bar{Y}_R) to the average national income (\bar{Y}) or the mean income of the low income regional population (\bar{Y}_p) compared to \bar{Y} . In the example, region A has the lowest per capita income for either regional income indicator; region C has the highest average income while regions B and D are ranked distinctly by the two indicators. Region B has the lowest average regional income compared to D, while region D has the lowest average income of the poorest segment of the population. It is clear from this that, if planning offices are to make choices among regions in rural development projects, considerable energy will have to be given to the construction of regional income surveys which permit comparisons among the average, sub-average, and supra-average regional income groups. Undoubtedly, over the coming years, the role of regional economic planning will rise in importance.

Table 3. Regional Income Indicators

Region (R)	\bar{Y}_R	\bar{Y}_p	\bar{Y}_R / \bar{Y}	\bar{Y}_p / \bar{Y}
A	100	25	0.53	0.13
B	200	50	1.05	0.26
C	350	60	1.84	0.32
D	260	40	1.37	0.21
Total (\bar{Y})	190	-	1.00	-

Notation: \bar{Y} = average national income.

\bar{Y}_R = average regional income.

\bar{Y}_p = average income of the regional population having less than the regional average income.

Several indicators have been posited as vehicles to compare the national or regional income distributional consequences of alternative investment projects. All of these indicators can only be applied with difficulty because of the severe weakness of all data on income distribution and the lack of local and regional income and product accounts. Once the income distribution (whether national or regional) is known it is also essential that the income levels of the direct beneficiaries be obtained and this may require costly local socio-economic surveys. Initially, the poverty redressal index (PRI) (equation (9)) could be a simple and direct measure of the number of beneficiaries arising from a national or local investment programme. Another applicable indicator could be the proportional change in the Gini coefficient per unit of project investments. Likewise, the PID can be obtained if the income distribution is known. This latter has the convenience that the cost-effectiveness of reducing income inequalities is better taken into account.

It is clear that no self-evident income distribution indicator can be universally recommended since they will have to be adapted in each country to the local data conditions and limitations which affect project analysts. Countries with a good data base will be able to introduce detailed regional income measures such as those discussed by Kalter and Stevens (61). Indicators which use rather fixed or arbitrary income categories (e.g. one-half the median income) to measure the distributional changes will be of little practical use in project evaluations unless a national agreement on the cut-off line for these categories can be obtained.

4.4 Foreign Exchange Objectives ^y

An often espoused objective of economic development is to increase the supply of foreign exchange. It is natural that this objective would be introduced into the micro-economic project evaluation by measuring the foreign exchange effects of individual projects. Hence, a project is justified on the basis that it increases foreign exchange more than another project. Some project manuals suggest that foreign exchange is not a legitimate, separate goal of project evaluation because it is accounted for in the shadow pricing of factors of production in the social cost-benefit analysis. Therefore, it is argued, that if all primary inputs are shadow priced using border prices reflecting international scarcities, the comparative advantage of project production activities is reflected in the net present value criterion. This procedure is appropriate when planning authorities are ascertaining the economic feasibility of an individual project without comparing it with a large number of project alternatives. However, if project designers want to rank investment possibilities, it is appropriate to calculate an indicator of the "partial" effects of a project on the foreign exchange earnings or savings of the country. In addition, external lending agencies are particularly interested in estimating such effects since they primarily supply the foreign exchange costs of agricultural, rural development or other investment projects in which they participate.

Two approaches are herein suggested for computing the foreign exchange consequences of a project. The first involves taking a view that economic and financial project data are severely limited. This approach is to make a conservative assumption regarding the traded share of the project's output. This seems particularly appropriate for rural development projects which initially tend to produce output of domestically consumed food or staple products; it is unlikely that the project will produce for direct export or import substitution but rather will benefit local consumers by making net additions to their already deficient diets.

Two crude ratios may be used to determine the partial foreign exchange impact of a rural development project. The first is a ratio of the net direct foreign exchange earnings per unit of project investment defined as the ratio:

$$F/I = PV_i(F_t) / PV_i(I_t) \quad (13)$$

^y This objective is closely related to the national income objective - foreign exchange problems are really constraints on national income growth. Governments often treat the foreign exchange goal as a separate objective.

An alternative to this simple foreign exchange-capital ratio is the ratio of the direct and indirect foreign exchange earnings to the capital outlays, the second part of the social marginal productivity ratio (see Chenery (20)) discussed earlier:

$$s(B/I) = s \left[\frac{PV_i (B_1 + B_2 + B_3)}{PV_i (I_t)} \right] \quad (14)$$

The only difference between the two ratios is that in the second the indirect effects are derived from the multiplier of the project outlays on imports and exports. In either case, the ratios are meant as only the simplest of all approaches and may not be employed to determine the social profitability of the projects in the same way as the social cost-benefit analysis.

A second approach to establishing the foreign exchange effects of a project is to calculate the domestic resource cost (DRC) per unit of foreign exchange earned or saved by the project. This ratio, discussed by Bruno (15), is a restatement of the net present value or the internal rate of return criterion which, instead of using the social profitability per unit of investment costs, uses the ratio of the domestic primary resource cost per unit of foreign exchange earnings and savings. Thus the DRC (or d_h) is defined as:

$$d_h = \frac{(V_j + P_k)}{(X_s - M_k)} \quad (15)$$

where V_j = the total domestic value added per unit of output, at shadow prices, each year.

P_k = shadow priced, nontraded commodities per unit of output each year.

X_s = foreign exchange earnings per unit of output, each year.

M_k = import requirements per unit of output, each year.

As shown, the DRC criterion may be applied to a project on an annual basis assuming that the project cost and benefit flows are uniform throughout the project's life. An alternative would be to obtain the present value of the ratio of the domestic value added to the present value of foreign exchange earned or saved per unit of output, and convert the irregular annual flows into uniform annual flows by applying the capital recovery factor to the uneven annual flows.

The domestic resource cost d_h is compared to a shadow foreign exchange rate d_o such that if d_h is less than d_o , the project is feasible. This can be shown to be equivalent to the net present value criterion such that the $PV_i \geq 0$ when the $d_h \leq d_o$. Likewise, when $PV_i < 0$, then $d_h > d_o$, indicating that the domestic resource cost per unit of foreign exchange earned or saved exceeds the opportunity costs expressed in the shadow foreign exchange rate.

The domestic resource cost criterion is not an efficient ranking device, just as the present value criterion cannot be used for ranking projects (see Bruno (15)). Since the implementation of each set of projects to be compared may cause the relative prices in the economy to change, it is not always possible to rank all projects, excluded from an initial feasible group, by their domestic resource costs. However, if the projects are small and they do not seriously alter the supply and demand conditions in the economy, the DRC may be taken as a close approximation for ranking project alternatives, particularly, discriminating among projects which may be producing either exceedingly large volumes of foreign exchange per unit of domestic resource cost or projects which appear to be extremely poor suppliers of foreign exchange. Projects in the middle ground between the extremes may not be ranked with the same degree of confidence.

Another criterion which has been used extensively, as reported by Balassa (3, 4), is based on the "effects method" of project evaluation. This method computes the benefits of a project as the increase in the domestic value added "... taken to equal changes in domestic incomes (wages, profits, rent and government revenue) associated with the project's implementation ..." (Balassa (3)). These project benefits are shown to be equal to the increase in foreign exchange stemming from the project computed in terms of the domestic currency. The costs of the project are variously identified as being "... three possible alternatives: identifying cost with the domestic cost of investment in the project, with the value of imports embodied in the investment, or with the loss in budgetary revenue." (Balassa (3)). Balassa demonstrates that the effects method of project evaluation is inappropriate for the determination of the feasibility of a project in the sense that the social cost-benefit analysis determines feasibility. The method excludes the non-capital domestic resource cost of executing a project and, therefore, implicitly assigns a zero shadow price to labour and non-traded domestic commodities, including those embodied in domestic investments. It is shown that with the inclusion of the missing factors, the effects method can be transformed into the domestic resource cost or the internal rate of return criterion and the feasibility of a project is obtained according to the usual social cost-benefit criterion.

4.5 Regional Economic Growth

An important objective of rural development programmes is to improve the balance of economic growth and per capita incomes among regions, placing special emphasis on low income regions. Direct project effects have been referred to in previous sections, where the increase in net farm income, employment or foreign exchange is used to determine project feasibility and ranking, although not necessarily from the viewpoint of regional authorities. Therefore, it is necessary to consider the indirect or secondary impacts of project investment on cash incomes within the region. The regional secondary effects of a project will differ from secondary effects attributed to a project at the national level. The major difference lies in the extent of the secondary income expansion. At the national level the net benefits of the multiplier effect may be quite small since the cost of displaced output reduces the magnitude of gross secondary benefits and since resources being used in one project are drawn from alternative uses throughout the economy. At the regional level, the cost of resources displaced from other regions is not a part of the project's secondary costs. The gross regional project benefit is regional value added, i.e., gross project benefits less the purchase of inputs from outside the region. A multiplier effect at the regional level is fully operative for cash incomes at three levels: wages and profits spent within the region; the regionally spent portion of value added of input-supplying industries; and the value added of output processing firms. For the region one would have to estimate the portion of extra income spent and the total amount of new added expenditure generated by the project within the region itself.

For each year one would obtain for the region:

$$R = \frac{b}{1-b} (Y + W + Z), \quad (16)$$

where b is the fraction of annual project cash income spent within the region, Y the net project cash income retained within the region (net of all loan repayments and transfers of income to other regions), W the value of annual cash wage payments, and Z the value of net income and wage payments of input-supplying and output-processing activities within the region. If 75 percent of the regional income is spent ($b = .75$), then the regional multiplier effect is 3.0 ($Y + W + Z$). It would be the maximum secondary expansion assuming no additional induced secondary investments arising from the project. In each case the value of b should be carefully justified and a high degree of regional interdependence established before secondary income expansions are included in computing project benefits. Furthermore, it is cash income that is relevant in each case so that the marketable proportion of gross and net benefits will have to be estimated for each rural development project.

A second approach in determining the local effects of a development project is to determine the direct consequences on the regional income distribution. Following Kalter and Stevens (61), it might be possible to estimate the income consequences on separate regions in a rural development programme. On the one hand, the regional benefits are defined. They should be a measure of regional net incomes stemming from the project investments both inside and outside of the region, identifying those net benefits which accrue to individuals within the specified region. A project is said to change the income distribution if "... the distribution of project net benefits is non-proportional to the income distribution projected to occur without the project in question." (Kalter and Stevens (61); p.207). The income distribution effects will be the difference between the net benefits accruing to the regions and the payments made by the regions in order to receive the project benefits. These latter payments include the tax payments made to finance the project's construction including income, sales, import or export taxes. These taxes payments are assumed to be made in the same proportion in which income, sales and other taxes were paid by the region in the past. To the extent that the region pays more or less than its usual burden of taxes, a reimbursement adjustment must be included which is the difference between what is actually reimbursed by the region and the "proportional reimbursement" defined as the reimbursement that would have been made using the traditional tax payment share of the region.

To the extent that debt repayments incurred in order to undertake the project can be separated from the regional net benefits, then it might be advisable to include them as a separate item in the calculation of the regional net distribution benefits.

The final component of the regional net benefits is the operating maintenance and replacement costs which the region must make during the project's operating phase. To the extent that these operating, maintenance and replacement costs are paid by other regions then, of course, the net regional benefits are greater. This also holds for the other costs of the project. The component parts of the net regional benefits to region 1 are shown as follows:

$$B_1^1 = PV(B_1) - \left[Z_1 + \{PV(R_1) - K_1 PV(\sum_r^R R_r)\} + PV(O_1) \right] \quad (17)$$

where $PV(B_1)$ = the present value of the net benefits to region 1.

Z_1 = the initial payments made through taxes by project beneficiaries to finance the project construction.

$PV(R_1)$ = the present value of the actual repayments (excepting taxes) made by region 1.

$PV(\Sigma R_r)$ = the present value of total repayments made by all regions for the development programme.

K_1 = regions 1's proportion of the total initial tax paid by all regions.

$PV(O_1)$ = the present value of the operating, maintenance and replacement costs incurred by region 1.

It is obvious that this technique of estimating the regional distributional impacts of rural development programmes requires data on the distribution of public sector tax revenues among regions and beneficiary groups. However, if the project cost and benefit flows are known and if the beneficiary group is well defined, it is possible that the volume of taxes paid by the beneficiaries will be small and the principal components of the project repayments will be the direct reimbursements of the initial construction cost and the operating costs of the project, i.e. the value of K_1 in the previous equation will be very small.

The spending generated by an investment may also lead to additions to national and regional employment. The direct employment generation of a project has been previously discussed. Initially, the unskilled labour required per unit of output of input-supplying and output-processing industries may be obtained on the basis of standard labour requirements for these industries. But it should be emphasized that to the extent that employment in other activities within the region is displaced, it must be treated as a negative contribution within the overall, regional employment estimates.

5. SIMPLE MULTIPLE OBJECTIVE EVALUATION PROCEDURES

5.1 Introduction

In an earlier section (3.3) the difficulty of introducing multiple objective analysis into project evaluation is raised as a central issue in designing measurable investment criteria for agricultural project evaluation. Four major objectives are considered including the efficiency goal, the employment-income distribution objective, the foreign exchange objective and the goal of more equitable regional (urban-rural) development.

In the preceding section, single objective evaluation criteria are suggested for circumstances in which decision makers are concerned only with the partial effects of a project. It is obvious that attention must be given to combining these partial effects in a way that the goals of policy makers are introduced. The purpose of this section is to explore various ways in which these partial effects might be combined or weighted so that projects are ranked for the various combined criteria. From the onset, it is important to clarify for those who expect a theoretically pure and satisfying way of identifying and combining policy makers preferences that they likely will be dissatisfied. Rather the proposed procedures are thought of as supplementary information to an informal decision-making process that presently goes on with little or no formal project analysis. A small improvement in existing planning procedures is proposed as a first step toward more complicated methods that might be employed at some future time when detailed project data are known.

A further issue concerns whether the objectives are expressed in general or specific terms. Thus, a specific goal might be to "increase the production of a product x by y amounts", while a general objective might be to "increase the production of x ". Experience in the use of scoring models for planning shows that it is easier to obtain initial acceptance of the goals when they are stated in broad terms, while the introduction of specific statements of precise targets is made at a later stage after the scoring system has evolved.

Once policy makers have accepted a list of objectives (O_1, \dots, O_m) , the succeeding step is to establish the weights on each objective.

Two approaches are recommended for the preliminary introduction of multiple objective considerations into project evaluation. Both of the approaches fit situations in which little is known about the multiple partial effects of the projects. While data may be available for a simple benefit-cost analysis for a few projects, a number of project alternatives may not have been studied to the detail that allows for a full-fledged social cost-benefit analysis.

The first approach is one in which expert opinions are elicited through a systematic interview technique called the Delphi method. The results of the interview technique are used to produce scores on the effects of each project on each objective. A scoring model is combined with the Delphi technique to obtain combined project scores and project rankings.

The second approach involves the combination of the partial effects quantified in previous sections with alternative weighting factors which approximate policy makers preferences for the separate economic goals. This will allow for the ranking of projects using the combined project performance measures.

While it is important to introduce a wide range of multiple objectives it is also important that the efficiency objective not be made subordinate to all other objectives in the group of objectives under consideration. Likewise, the efficiency objective may be introduced via the goal of maximizing the foreign exchange contribution of a project. This is done by the inclusion of foreign exchange shadow prices. But using the simple scoring model and the Delphi method the objectives cannot be promoted by the proper (shadow) pricing of factors or production but must be assigned a separate performance score.

5.2 The Delphi Method

Stemming from the lack of historical experience and economic and social data on the execution of rural development programmes, subjective judgements are needed in order to undertake even a simple financial cash-flow analysis. Furthermore, a variety of heroic assumptions principally based upon expert or observer evaluation may have to be made to complete a detailed social cost-benefit analysis. Therefore, recognizing that reliance will have to be given to these subjective judgements, it is far better that they be obtained in a systematic and coherent fashion, rather than in a disorganized and spontaneous way. Personal judgements of technicians, experts and policy makers may be requested on a variety of topics including, for example, the objectives of economic and social policy, the choice of beneficiary groups, the selection of regional priorities, the design of individual projects and sub-projects, and the values of project coefficients such as yields per hectare, health visits per nurse, and investment costs per kilometre.

The Delphi method, which has gained respect in recent years, is a method by which the expert opinions of individuals, panels or committees are systematically combined to produce information on the feasibility, desirability and other features of various policy options. Linstone and Turoff (68) have thoroughly surveyed the application of this method to government, industry, social, economic and political questions. The Delphi technique is a systematic interviewing technique to obtain an expression of goals, opinions, and judgements of individual participants. The results of the judgements are weighted and combined in some appropriate fashion to obtain a performance value for the various project or policy options under review. The final result may be to rank projects or determine their feasibility or combine sub-projects or activities.

The method, which has several variants, is applied in the following specific stages: determination of the principal issues to be considered, an analysis of the options open to achieve these objectives or to resolve the issues, setting the initial position of each expert, exploring the areas of disagreement among various experts, evaluating the causes for disagreement and, finally, determining the options open to resolve the issues. In the policy Delphi (Turoff (116)) participants are asked to numerically rate the options or instruments according to the criteria of desirability, feasibility, importance and confidence. A rating scale is set for each of these alternative criteria so that the participants are able to rank the policies or projects according to whether they are, for example, very desirable, desirable, somewhat undesirable or very undesirable and as definitely feasible, possibly feasible, possibly infeasible, definitely infeasible. For example, participants may be asked to give their opinion as to whether a project will benefit the lowest income groups within the target regions and the alternatives may include (1) very probable, for a (subjective) probability greater than 0.75; probable for a probability greater than 0.5 but less than 0.75; improbable for a value of less than 0.5 and greater than 0.25 and very improbable for a probability of less than or equal to 0.25.

In the preparation and design of rural development projects the Delphi interview method may be used for two purposes: The identification of the principal social and economic objectives of planners and policy makers and estimating the probable consequences of a project investment upon the individual objectives that have been established. Furthermore, within the literature on the Delphi method some attention has been given to the question of determining the weights on the distinctive objectives in order to combine them with the probable outcomes of the projects for each of the relative objectives. ^{1/}

^{1/} See the report by Gum, Roefs and Kimbell (35) in which an effort is made to quantify preference weights on societal goals and sub-goals for water resource investments.

There are no special rules for the application of the Delphi method. However, there are several common difficulties referred to by Linstone (68). These include (1) a tendency by participants to heavily discount the future, making judgements oriented to immediate goals; (2) a tendency of the participants to attempt to predict consequences far into the future, although they may have serious uncertainties regarding the prediction; (3) a tendency to try to simplify statements of objectives or results in order to keep conflict to minimum; (4) problems in executing the Delphi technique including the selection of participants, designing questionnaires, construction of feed-back and review mechanisms; (5) the so-called optimism-pessimism bias which is referred to as "... a bias toward over-pessimism in long-range forecasts and overoptimism in short-range forecasts." Linstone (68, p.84); (6) a tendency to oversell the value of Delphi techniques; and (7) a possibility that participants will systematically deceive or design their answers to increase their own immediate gain from the exercise.

The Delphi interview techniques is appropriate for rural development projects in which project beneficiaries participate in designing and structuring the programme. Various interest groups such as small farmers, landless workers, urban dwellers, regional planners and politicians, and government bureaucrats can be asked to provide assessments of whether alternative sub-projects or programmes would be included in rural development programme. The respondents could be asked to rank objectives of rural development programmes and within these objectives a variety of subgoals including alternative levels of income, employment and social services for the region. The alternatives may be ranked using a scale of zero to 100 points, asking each participant to allocate the 100 points among the several objectives, so that the sum is always equal to one hundred. An alternative approach is to ask the participants to rank the objectives according to a fixed scale of one through five or one through six and then averaging these results across all participants or the interest groups. The Delphi technique is closely tied to the construction of scoring models which is the quantitative representation of the results of the Delphi interviews. The design and construction of scoring models is now discussed.

5.3 Scoring Models

In this section a project evaluation system is elaborated for the assignments of scores to each project by informed technicians. Scoring models have been discussed especially in conjunction with the evaluation of industrial research and development programmes.^y A substantial gain in clarity and in organization is achieved by the scoring technique because of the explicit enumeration of preferences for alternative planning goals. Likewise, project evaluators are encouraged to explicitly express their judgements on the potential contribution of each project to each planning goal.

Scoring individual projects involves the following steps: (1) the selection and enumeration of the social and economic objectives of the investment programme; (2) the determination of a weighting scheme that reflects policy makers assessments of the relative importance of each of the objectives; (3) the choice of a numerical scale for measuring the value of the contribution of a project to each objective in (1) above; and (4) the determination of a ranking mechanism (function) that combines the policy makers preferences and the project scores in obtaining a total score for each project. As a final step (5), all possible projects under consideration are ranked according to their individual scores.

^y See Moore and Baker (83) and Dean and Nishry (25).

A project scoring model has the following properties and elements as shown in the accompanying Table 4. ^y Decision makers identify m objectives O_1, O_2, \dots, O_m . In some (to be specified) fashion, m weights W_1, W_2, \dots, W_m are obtained which express the relative importance of each of the objectives during the planning phase. Thus, for example, objectives might be to maximize income, to obtain an improved distribution of income or to increase foreign exchange earnings. In the system (i) preferences are expressed, (ii) projects are scored and (iii) projects are ranked.

The initial problem is to outline a list of objectives for the economic sector that is under study. It is unnecessary that all decision makers and technicians agree on the exact number, form or specification of the objectives. Some agreement might be made, to limit the number of objectives to a manageable total that can later be weighted by the policy-makers. The objectives should be independent, in the sense that each can be assigned a separate weight and is conceived as a separate preference by policy-makers.

Table 4. Elements of a Scoring Model

Objectives	O_1	O_2	\dots	O_m	Total
Weights	W_1	W_2	\dots	W_m	Score (S_i)
Project					
1	P_{11}	P_{12}	\dots	P_{1m}	$S_1 = \sum_j^m W_j P_{1j}$
2	P_{21}	P_{22}	\dots	P_{2m}	$S_2 = \sum_j^m W_j P_{2j}$
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots
m	P_{n1}	P_{n2}	\dots	P_{nm}	$S_n = \sum_j^m W_j P_{nj}$

^y See especially Dean and Nishry (25).

The choice of weights is the most crucial step in constructing the system since, depending upon the relative importance attached to each goal, the structure and composition of the investment programme will be greatly affected. Furthermore, the underlying structure and composition of the weights is a sensitive political decision, reflecting not only the importance of each goal but the ultimate political structure of the decision making process of the society. Thus, to cite some examples, a simple democratic process might require the selection of the weights, giving equal importance to the preferences expressed by each member of the group. A purely representative political process might attach equal importance to the views expressed by each representative. A purely centralized system would, perhaps, set the weights according to the views of a small group of economic and social planners. Evidently, there is a continuum of possible ways to select the individual participants, and, hence, the choice will be made by the appropriate planning authorities and by a mechanism chosen by each society.

Assuming the objectives have been identified, two procedures are now elaborated. The first is based on the assumption that all policy makers interviewed are of equal importance in expressing their views and that the objectives are ranked by a pre-set scale based on the number of objectives under consideration. Once the interview group is determined the preference weights are derived.

The first weighting scheme might be called the "mean preference" alternative. Each government official examines a list of objectives and ranks the objectives one through the total number of objectives. Suppose there are six objectives and three officials. In terms of the scale, the objectives are ranked as in the first three columns of Table 5.

Table 5. Preference Weights Estimates

Objective	Individual Rankings			Mean Ranking	W_j
	1	2	3		
1	6	2	2	3.3	31.7
2	5	4	1	3.3	31.7
3	2	5	3	3.3	31.7
4	3	6	4	4.3	41.4
5	4	3	5	4.0	38.5
6	1	1	6	2.6	25.0
				Total	200.0

Individual 1 ranks objective 1 in first position (six points); objective 2, second (five points); objective 3, fifth (two points); etc. The highest ranked objective receives the largest value. Then, as shown, the values are averaged for the three individuals. Each individual is assigned equal weight in the scheme, and the results can be described as a "compromise" weighting. The final weights can be adjusted to provide any particular total sum of the weights W_j . Following the notation of Table 4, the score (S_i) of any project i is equal to

$$S_i = \sum_j^m W_j P_{ij} = 31.7 P_{i1} + 31.7 P_{i2} + 31.7 P_{i3} + 41.4 P_{i4} + 38.5 P_{i5} + 25.0 P_{i6} \quad (18)$$

Assuming that the projects are scored on a scale of one through five, a "perfect" project (a project receiving a score of five for each objective P_{ij}) would receive a total score of 1 000.

Two variations on this system of estimating weights are now considered in order to highlight an obvious weakness of the above method. In Table 5 the decision makers are restricted to a strict ordering according to a pre-established scale. Not only are ties among two or more objectives prohibited, but the relative "distance" among the objectives is fixed. Hence, individual 1 of Table 5 cannot pick objectives of equal value, even though the average ranking yields equality among the first three goals.

To extend the range of choices for policy makers, ties are admitted. One may proceed as shown in the following example:

Table 6. Preference Weights

Objectives	Individual Ranking			Mean Ranking
	1	2	3	
1	6	6	2	4.7
2	6	5	4	5.0
3	5	4	5	4.7
4	4	3	5	4.0
5	3	2	3	2.7
6	3	2	3	2.7

whereby, individual 1 expresses equal preferences for objectives 1 and 2 and for objectives 5 and 6.

An alternative way of computing the weights could be as follows:

Table 7. Mean Preference Weights

Objectives	Individual Ranking						Mean Preference
	1	2	3	1	2	3	
1	6	6	1	5.5	6.0	1.0	4.2
2	6	5	3	5.5	5.0	3.0	4.5
3	5	4	2	3.5	4.0	4.5	4.0
4	5	3	1	3.5	2.5	6.0	4.0
5	4	3	2	2.0	2.5	4.5	3.0
6	3	2	4	1.0	1.0	2.0	1.3

In Table 7, if two objectives fall into the first two slots, but are of equal value (6 and 6), an average of the corresponding position numbers (6 and 5) is used, i.e. 5.5 for individual one. Likewise, objective 5, for individual 1, is in position 2 of the rankings and, therefore, receives a weight of 2. The main result of this method is to permit a wider spread among the objectives.

The final step is to determine the contribution of each project. This is based upon a scale of score values set by the project evaluation team. Assume that a scale of one to five is chosen—a project receiving a score of five for objective one makes the maximum contribution and a score of one is the minimum contribution.

Consider the separate example of Table 8 below:

Table 8. Project Scores and Rankings

Project \ Objectives W _j	O ₁ 18	O ₂ 74	O ₃ 54	O ₄ 54	Total = 200
1	5	4	2	4	710
2	1	1	5	4	670
3	3	3	1	4	546

There are four objectives with weights, respectively, of 18, 74, 54 and 54. There are three projects each with a score for each objective. Project one receives scores of 5, 4, 2 and 4, respectively, for each objective and a total score of 710 is obtained,

$$S_1 = 18(5) + 74(4) + 54(2) + 54(4) = 710 \quad (19)$$

There are two serious inherent problems in the application of scoring techniques. The first is in the choice of the scoring scale and the second is in the choice of the scoring and evaluation group. The scale can be treated as a range of project effects that can be correlated with quantitative values. For example, a project output-capital ratio can be transformed into a numerical scale. Employing a point's scale of five to one, a project output-investment ratio of (say) .35 - .30 might receive five points, of .30 - .25, four points, etc. Considering the difficulty in determining these values the scale should be limited to about five intervals.

The choice of a scoring and evaluation (Delphi) group is crucial in the application of the technique to rural development projects. Several criteria should be considered. First, the members should be reasonably familiar with the projects, activities or programmes to be ranked. At least one member of the committee should be chosen from the entity directly responsible for making the feasibility studies. To maintain a degree of objectivity, people should be included from outside of the group expected to benefit from the project investments. The number of committee members should be no more than five, otherwise it is difficult to obtain agreement of the group on the score of each project or activity.

5.4 Combining Single Goal Indicators

5.4.1 Introduction

The present section analyses the alternative methodologies for combining multiple objectives through simple measures of project performance to ascertain project feasibility ranking. The weighted combination of individual objective measures will be effectuated in a variety of ways including: (1) a combination of the benefit-cost ratio with the scoring technique; (2) combining equity and distributional considerations in the benefit-cost ratio; and (3) a numerical ranking scheme which allows for the simple weighting of project performance for a number of single objective measures. The criteria at this stage do not require the use of a complex programming technique such as goal programming or multi-level programming (33). A rather simple procedure is required to provide more information to policy makers who must make choices among different projects. Clearly, these are not optimization techniques in the sense of consistent mathematical programme models, but they are techniques which can be applied and which will supply more information to policy makers than they would have received if they wait (often without result) for the economy-wide application of more sophisticated programming models.

5.4.2 Benefit-Cost Analysis and Non-quantifiable Effects

A first approach to combining several economic objectives is to use the benefit-cost or cost-effectiveness ratio and combine it, in some fashion, with the scoring model discussed in previous sections. This approach, suggested by Acar (1), is an appropriate technique for this purpose, using the benefit-cost ratio as a principal criterion and weighting the ratio by the additional effects that a project may have on social objectives. Thus, assume first of all that a project has been evaluated using a standard economic cost-benefit ratio. This ratio could be used to obtain a ranking of the project alternatives, but these may change if the project has non-efficiency consequences that have not been accounted for in the benefit-cost analysis. The solution is a benefit-cost ratio adjusted by a factor I_s as follows:

$$(B/C)^* = (B/C) (I_s) \quad (20)$$

where B/C = the economic benefit-cost ratio,

I_s = an "index of suitability" and

$$1 - a \leq I_s \leq 1 + a \quad (21)$$

The index of suitability, which modifies the economic benefit-cost calculations, is based upon the policy maker's judgement as to how much he would allow for shifts away from the efficiency criteria (by factor a) such that the suitability index can be no smaller than $(1 - a)$ and no larger than $(1 + a)$. An example demonstrates the value of this particular relationship. In Table 9 three projects are shown with cost-benefit ratios ranging from 2.0 to 1.5. Under this criterion it would be appropriate to choose project (3) with the highest priority, project (1) next, and then project (2) with the lowest priority. However, assume that on the basis of a scoring model, non-efficiency effects of the three projects have been scored and these scores range from 53 to 203. These scores are now transformed into the range $(1 - a)$, $(1 + a)$. If it is assumed that policy makers will not permit a greater variation than twenty percent away from the efficiency level, i.e. $a = 0.20$, then the scores ranging from 55 to 223 are transformed into the segment 0.80 to 1.20. This transformation (following the explanatory footnote of Table 9) gives a modified benefit-cost ratio for each of the three projects. This new ratio changes the rankings of the three projects because the benefit-cost ratio of the highest ranked project is reduced by twenty percent because it had the lowest score, and the lowest ranked project with benefit-cost ratio of 1.58 has its numerical value increased by twenty percent because it had the highest score in the non-efficiency category. In the example, project (1) remains in its relative position after the modified benefit-cost calculations are made. While this procedure contains an element of arbitrariness because of the ad hoc selection of the coefficients the approach does provide a systematic means to combine the benefit-cost ratio with other social and economic objectives.

Table 9. Benefit-Cost Ratio and the Suitability Index

Project	B/C	Score	I_s	$(B/C)^*$
$(a=0.20)$				
1	1.65	170	1.07	1.77
2	1.50	223	1.20	1.80
3	2.00	55	0.80	1.60

$$I_s = 1 + u \frac{(2a)}{(v_M - v_m)}, \text{ where}$$

u = plus or minus deviation of each score from the mid-range score v'

v' = the mid-range score, the average of the highest and the lowest score

a = the policy standard for range of the scores, as in equation (21)

v_M = the highest score

v_m = the lowest score

For example, it might be possible to obtain scores for the social development components of the rural development projects such as health, education and nutrition programmes; they would be combined using the suitability index of the proposed criterion. Thus, if a project has a high benefit-cost ratio because it yields large increases in the net incomes of benefiting farmers from its production and production support components and if the social development component of the project has a low degree of cost-effectiveness, this can be introduced via a score. This procedure would appear to be superior to one of merely neglecting the social development components of a rural development project.

Likewise, it would be possible to extend the scoring analysis to include factors such as the indirect impacts of the investment projects as well as the social consequences of individual project components. Thus, a project which is within a very poor region may have its benefit-cost ratio adjusted by an index of suitability which is inversely proportional to the level of regional per capita income. As recommended, this index can easily be constrained within limits desired by the national or regional planners so as to avoid overwhelming the efficiency effects of the project with the non-efficiency elements.

These procedures are related to a suggestion by Professor Harberger (39), who proposes that the standard efficiency benefit-cost ratio may be combined with information on the effects of a project on the poorest income groups. Assume for the sake of discussion that project's costs are separated into two categories: the total benefits and costs of a project (irrespective of who might receive them) and the benefits and costs that go to the poorest segment of the rural population. The former will be called the benefits, B , and the costs, C , and the latter will be designated as the benefits, B_p , to the poorest groups and the costs, C_p , to the poorest groups.

The distributional benefits of a project should not be allowed to make up more than a certain share of the total project net benefits perhaps no more than 20 percent. Any project with net distributional benefits that exceeded (say) 15 percent of its net efficiency benefits would have its distributional benefits constrained to that 15 percent differential so that the project would not have an unfair advantage in any comparison made with an "efficient" project which had no distributional benefits at all. Thus,

$$(B_p - C_p) / (B - C) \leq a. \quad (22)$$

5.4.3 Weighting Multiple Objectives

Short of undertaking a complete programming exercise of the type suggested by Candler and Boehlje (17) or Sfeir-Younis and Bromley (106), a compromise solution is to use the separate rankings obtained from the partial indicators of project performance and weight the rankings to obtain an aggregate project ordering under alternative (preference) weights for each of the economic and social objectives. For each of the rural development objectives, an indicator is chosen from the alternatives discussed in previous sections and is used to rank each of the projects according to each of the individual objectives.

There are two types of ranking that may be used for this purpose - the ordinal or the cardinal rankings. The former, obtained by using a pre-set scale, is the ranked position of each of the projects for each of the objectives. The income objective is represented by the benefit cost-ratio, the employment objective by the employment-investment ratio and the balance of payments objective by a foreign exchange-investment ratio or domestic resource cost criterion.

An example of such a ranking is shown in Table 10 where five projects and three objectives are represented and the two systems of ranking are compared. The ordinal ranking shows that the project with the highest value for a given objective receives a ranking of five, the next a ranking of four and the lowest receives a ranking of one. This is an ordinal ranking because the determination is whether a project's position is higher than the other and the ranked "distance" between the two projects is of no concern under this scheme.

Table 10. Ordinal (Y^P , E^P , F^P) and Cardinal (\bar{Y}^P , \bar{E}^P , \bar{F}^P) Project Rankings by Objective

Project	Benefit-cost ratio (BCR)	Employment capital ratio (ECR)	Foreign exchange-capital ratio (FCR)	Rankings					
				Y^P	\bar{Y}^P	E^P	\bar{E}^P	F^P	\bar{F}^P
A	1.8	0.8	1.2	4	1.14	5	1.86	2	0.61
B	2.3	0.5	0.6	5	1.46	4	1.16	1	0.30
C	1.2	0.35	2.7	2	0.76	3	0.81	4	1.36
D	1.1	0.2	1.8	1	0.70	1	0.47	3	0.91
E	1.5	0.3	3.6	3	0.95	2	0.70	5	1.82
Average	1.56	0.43	1.98						

5 = highest ranking

1 = lowest ranking

An alternative procedure is to use a cardinal ranking which takes into account the "distance" between the projects for each of the investment criteria so for the income objective Y, project A is ranked the highest with a numerical value of 1.46, project B is ranked next with a value of 1.14, and so forth, until project D is ranked with a value of 0.7. These cardinal values are obtained by taking the ratio for each criterion of the individual value for the project to the average for each criterion such that, for example, for project B, $1.46 = (2.3)/(1.56)$ for the BCR criterion. Thus, the ordinal ranking for each of the objectives is obtained by the following relationships:

$$\bar{Y}^P = BCR^P / \frac{\sum_{i=1}^n BCR^P}{n} \quad (23)$$

$$\bar{E}^P = ECR^P / \frac{\sum_{i=1}^n ECR^P}{n} \quad (24)$$

$$\bar{F}^P = FCR^P / \frac{\sum_{i=1}^n FCR^P}{n} \quad (25)$$

for each project p and n projects.

The purpose of the exercise is to combine the three objectives - income, employment and foreign exchange - into a single ranking such that the ordinal ranking is defined as:

$$R^P = y \bar{Y}^P + e \bar{E}^P + f \bar{F}^P \quad (26)$$

where p is any project and R is its respective ranking for the weights y, e and f such that $y + e + f = 1$. Likewise, the cardinal ranking is defined as:

$$\bar{R}^P = y \bar{Y}^P + e \bar{E}^P + f \bar{F}^P \quad (27)$$

For each set of weights y, e and f there will be a distinct ranking R_j of the projects. For example, in Table 11 two alternative weights are shown for the two ordinal rankings (R_1, R_2) and the two cardinal rankings (\bar{R}_1, \bar{R}_2) . Under the relationship R_2 , the ranking across each of the individual objectives is

$$E = 3.75 = (0.25) (3) + (0.25) (2) + (0.50) (5), \text{ and} \quad (28)$$

the value of project E = 3.75 is a weighted average of project scores under the ordinal ranking. Similarly, for the cardinal ranking \bar{R}_2 for project E with the same weights

$$E = 1.33 = (0.25) (0.95) + (0.25) (0.70) + (0.5) (1.82) \quad (29)$$

Table 11. Ordinal (R_1 , R_2) and Cardinal (\bar{R}_1 , \bar{R}_2) Combined Rankings

R_1 (.33, .33, .33) ^y	R_2 (0.25, 0.25, 0.50)	\bar{R}_1 (0.33, 0.33, 0.33)	\bar{R}_2 (0.25, 0.25, 0.5)
A = 3.67	E = 3.75	A = 1.20	E = 1.33
B = 3.33	A = 3.25	E = 1.16	A = 1.07
C = 3.33	B = 2.75	C = 0.98	C = 1.07
D = 3.00	C = 2.25	B = 0.97	B = 0.81
D = 1.67	D = 2.00	D = 0.69	D = 0.76

^y The project ranking factors (y, e, f) such that $y + e + f = 1$.

It is important to emphasize that the weights y, e and f are not social welfare preference weights and that the assignment of value 0.50 to the balance of payments objective does not mean that it is twice as important as either the income or the employment objective which each have weights of 0.25. Rather it means simply that the ranking of the project has twice the value as the ranking of the other two objectives, i.e. they are merely relative weights. It is an additional step to make these weights y, e and f consistent with preference weights as discussed in McGaughey and Thornbecke (76). It is enough to state at this point that it is possible to transform the weighting equation into a relationship that would represent the preference weights of the policy maker, but it is necessary to obtain equivalent preferences values for each objective from the policy maker.

It is useful to note that the proposed procedures will not always produce the same orderings for the ordinal and the cardinal rankings. For example, under comparisons R_1 and \bar{R}_1 , for the ordinal ranking there is a small numerical gap between the highest and the next highest projects A and B, and for the cardinal ranking there is a substantial gap between projects A and B. Likewise, under the cardinal ranking project B does very poorly relative to the other projects and this poor performance is more reflected in the value that it receives for the cardinal ranking, $B = 0.38$. Projects B and C have different positions within the ranking since project B has a high ordinal ranking of 2.75, while it has a very low cardinal ranking of 0.81 due to the relative separation between the projects is more nearly reflected by the ranking \bar{R}_2 .

The proposed ranking mechanism is designed to be of utility to project designers and planners when there is a serious underlying lack of information about the effects of rural development projects in different regions.

The objective of the recommended evaluation procedure is to contribute more information to the existing decision making process by identifying projects which are likely to perform well under many circumstances and those which might be expected to do poorly under a wide range of weights that policy makers might place on these objectives. No single decision rule or procedure - however consistent and theoretically proper - can be the sole or even main criteria for making investment decisions.

It is unlikely that policy makers will be able to express the "weights" that they place on economic and social objectives. This means that the economic planner will have to follow a procedure that uses a wide range of possible weights giving preponderant importance to one and then another objective or by giving similar importance to two or more objectives. The number of such possibilities are large and those that seem the most relevant ones will have to be worked out by planners. For each set of possible weights a ranking of the project possibilities will be obtained, and for several rankings (and set of weights) planners may begin a process of choice and elimination. There often will be projects that are ranked high for many of the weighted rankings - these projects can be chosen with greater confidence as those contributing to a wide variety of economic and social objectives; likewise, projects that perform poorly (ranked low) for many alternative weights can be eliminated with a greater degree of confidence. Project D (Table 11) ranks poorly and project E does well under a number of presented circumstances. Of course, as new projects are discovered and designed these should be added and the procedure repeated. Likewise, projects which are discarded at one time should constantly be reviewed as a part of the procedure because they might rank higher at a later date. Therefore, the essence of this system is to continuously evaluate and re-evaluate a constantly changing batch of project alternatives.

The procedure can be applied to circumstances in which there are rural development projects containing both productive and social elements, as in the rural development programmes of Mexico and Colombia. Thus, if rural development projects can be appraised under criteria such as the cost-benefit ratio, employment-capital ratio, and domestic resource cost ratio, one can proceed to apply alternative ranking weights and point out the projects that seem to perform especially well.

A second alternative would be to use the procedure to weight the internal rural development project elements. Suppose that there are projects A and B, each with two major categories of investments - production development and social infrastructure. If the productive activities can be appraised using the benefit-cost ratio or the employment-capital ratio and the social activities can be evaluated using a form of the benefit-cost ratio or, lacking data, a cost-effectiveness ratio, then weights can be set on the importance of the productive and social inputs of the project. If planners assume that the productive support benefits are of primary importance and the social services are of secondary importance, they might attach a relative weight to these two elements of (say) .75 for production effects and .25 for social development effects. This would limit the extent to which any one of the separate services of the project, productive or social, would overwhelm the ranking of the project.

One can define a ranking:

$$R^P = x X + s S \quad (30a)$$

$$= x (BCR) + s (CER) \quad \text{and} \quad (30b)$$

$$x + s = 1$$

to obtain a weighted average of its production and social development effects wherein the production development effects (X) are represented by the benefit-cost ratio (BCR) and the social development impact (S) is represented by the cost-effectiveness ratio (CER). Following the example of Table 12, there are two projects A and B each with production and social development components X and S, measured by the benefit-cost ratio and the cost-effectiveness ratio. Project A has a benefit-cost ratio of 2.8 and project B a benefit-cost ratio of 1.9. Project A has a cost-effectiveness ratio (say) for an education subprogramme of thirteen students per US\$100 expended in the programme and project B seventeen students trained per US\$100 expended in the programme. The cardinal ranking is obtained as in early examples as the ratio between the specific indicator and its average such that the production effect of project A is $1.19 = (2.8) / (2.35)$. Finally, a weighted ranking is obtained under the assumption that the production effects are weighted by the factor .75 and the social development effects by the factor .25. While project A has a higher production effect than B and project B a higher social development effect than A, project A is preferred. In fact, not until the social development weight is given a value of $s = .6$ and the production component a value of $x = .4$ are the projects equal in their overall rankings. The implications of such calculations in these comparisons provide policy makers with considerable additional information on the impacts of their decisions as well as the importance that one or another component might play in an investment.

Table 12. Ranking of Projects with Production and Social Sub-projects

Project	Production Component X = BCR	Social Component S = CER	Cardinal Ranking		Weighted Ranking \bar{R}_1 (0.75, 0.25)
			\bar{X}^P	\bar{S}^P	
A	2.80	13	1.19	0.87	1.11
B	1.90	17	0.81	1.13	0.89
Average	2.35	15			

$\bar{Y} \quad x = 0.75; \quad s = 0.25$

6. SENSITIVITY ANALYSIS

6.1 Present Procedures

Following the conduct of the initial social cost-benefit analysis a common technique is to incorporate effects of risk or uncertainty by preparing a detailed sensitivity analysis. This sensitivity analysis treats the benefit-cost ratio, the present value criterion or the internal rate of return criterion under the assumption that there are systematic differences in the important parameters making up the original calculations.

There is considerable literature on alternative ways of incorporating risk and uncertainty into project evaluation, notably, Pouliquen (91) and Reutlinger (94). These approaches emphasize estimates based upon either historical experience or technical perception of the probability that the benefits, costs, prices, outputs and other technical parameters will achieve the values that have been estimated under the initial certainty approach. Thus, for example, it is suggested that one can obtain an estimate of the probability distribution of project investment costs. This can be combined with appropriate probability distributions for inputs and outputs of the projects and they all can be combined into a probabilistic present value or benefit-cost criterion.

It is not the purpose of this section to present a detailed review of alternative approaches to treating risk and uncertainty in project evaluation. While most project evaluation manuals pay lip service to the importance of introducing risk and uncertainty, there are no widely used simple methodologies for introducing probability as an element of the project cost and benefit calculations. While specific projects may have been evaluated using such techniques, there is a considerable element of personal subjective judgement in determining the probability distributions for each of the individual cost and benefit flows. If a probability distribution is not known for every variable making up the net benefit stream, then the risk analysis is nearly meaningless. Therefore, probability analysis cannot easily be introduced at a practical level of evaluation of rural development projects which are composed of many sub-projects each with different technical, economic and social consequences. While one can conceive that probability estimates might be obtained for a simple agricultural project which produces, say, five or six commodities with a relatively well-known technology, it would not seem possible to do the same for a project that has ten or fifteen sub-projects each with a large variety of services and products. Therefore, in the foreseeable future it will be necessary to proceed using rather simple sensitivity analysis in which technicians make arbitrary adjustments in the important variables of the cost-benefit flows and check the response of the measures of project worth to these systematic variations in relation to the chosen criteria.

The current practice of international lending agencies as well as national planning groups is to approach sensitivity analysis in a rather pragmatic, conservative and somewhat arbitrary way. The sensitivity analysis usually proceeds along the following lines: first, the cost and benefit flows of the project are obtained using the "best estimates" of the individual technician in the field based upon recent historical experience; secondly, on the cost side, systematic increases are made in the investment and operating costs by ten, twenty and thirty percent over the project's life; thirdly, on the benefit side, variations are made to reduce the product prices, yields or similar variables by five, ten, fifteen, and twenty percent over the life of the project; fourthly, the internal rate of return of the project is recomputed for the alternative cost and benefit flows constructed from the percentage variations in the values indicated previously, showing thereby, variations in

the internal rate of return or benefit-cost ratio of the projects; fifthly, the internal rates of return are compared to some cut-off rate and if all or most of the internal rates of return, even under the more conservative cost and benefit variations, are acceptable the project is deemed viable.

Table 13 shows the simple sensitivity analysis used by external lending agencies in computing internal rates of return for candidate projects. In this hypothetical case a project has an initial outlay of US\$100 in year 0 and a uniform net benefit of US\$25 annually over ten years and an internal rate of return of 21.4 percent without any adjustment in the benefits or costs. The rate of return of the project is recalculated for operating and investment costs which are expected to increase by five, ten, fifteen and twenty percent, respectively, and annual project benefits are expected to diminish by factors of five, ten, fifteen and twenty percent. In the hypothetical example, the original rate of return is a respectable 21 percent, but it diminishes rather rapidly as adjustments are made in the benefits and costs of the project. Thus, if the project economist had underestimated investment and operating costs by five percent and overestimated project benefits by five percent, the internal rate of return would be fully seven percentage points less. It is rather easy to anticipate that project rates of return will be highly sensitive to variations in the costs and benefits.

Therefore, it is advisable that project evaluators undertake a more detailed cost and benefit sensitivity analysis than that just referred to. The project benefit and cost flows should be disaggregated into their most important components, including the technical coefficients and the prices - both shadow and market - used to obtain the real input and output flows. Hence, it might occur that a project's profitability is insensitive to some of these variables such as the price of labour or the price of foreign exchange and more sensitive to other variables such as the rate of interest, the price of domestic inputs or the price of skilled labour.

Table 13. Internal rate of return for percentage variations in costs and benefits. (Initial investment $I = 100$; annual benefits $B = 60$; annual costs $C = 35$; time period, 10 years.)

$\% \Delta B$	$\% \Delta TC$	0	+5	+10	+15	+20
0	21.4	17.9	14.5	11.2	8	
-5	17.7	14.1	10.8	7.5	4.3	
-10	13.7	10.2	6.8	3.2	0	
-15	9.6	6.0	-	-	-	
-20	5.1	1.3	-	-	-	

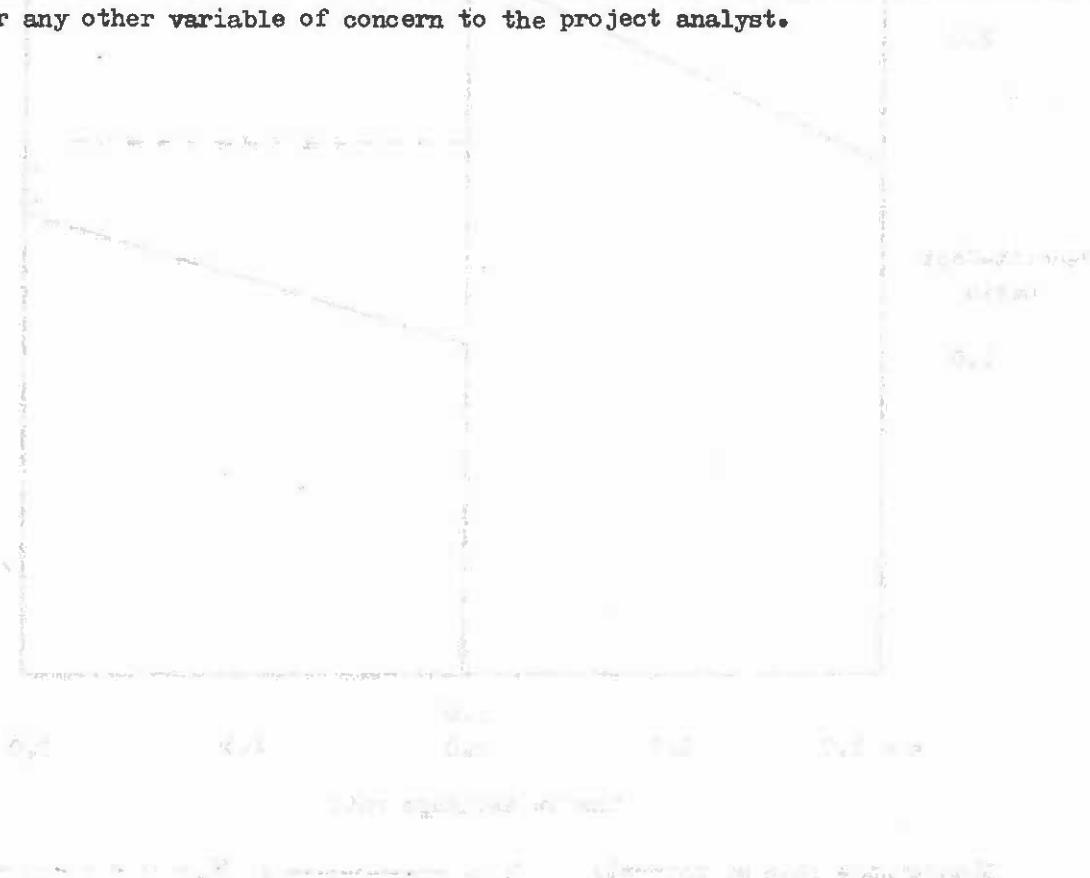
$\% \Delta TC$ = percentage increase in total costs (investment plus annual costs).

$\% \Delta B$ = percentage decrease in benefits.

(-) = a negative internal rate of return.

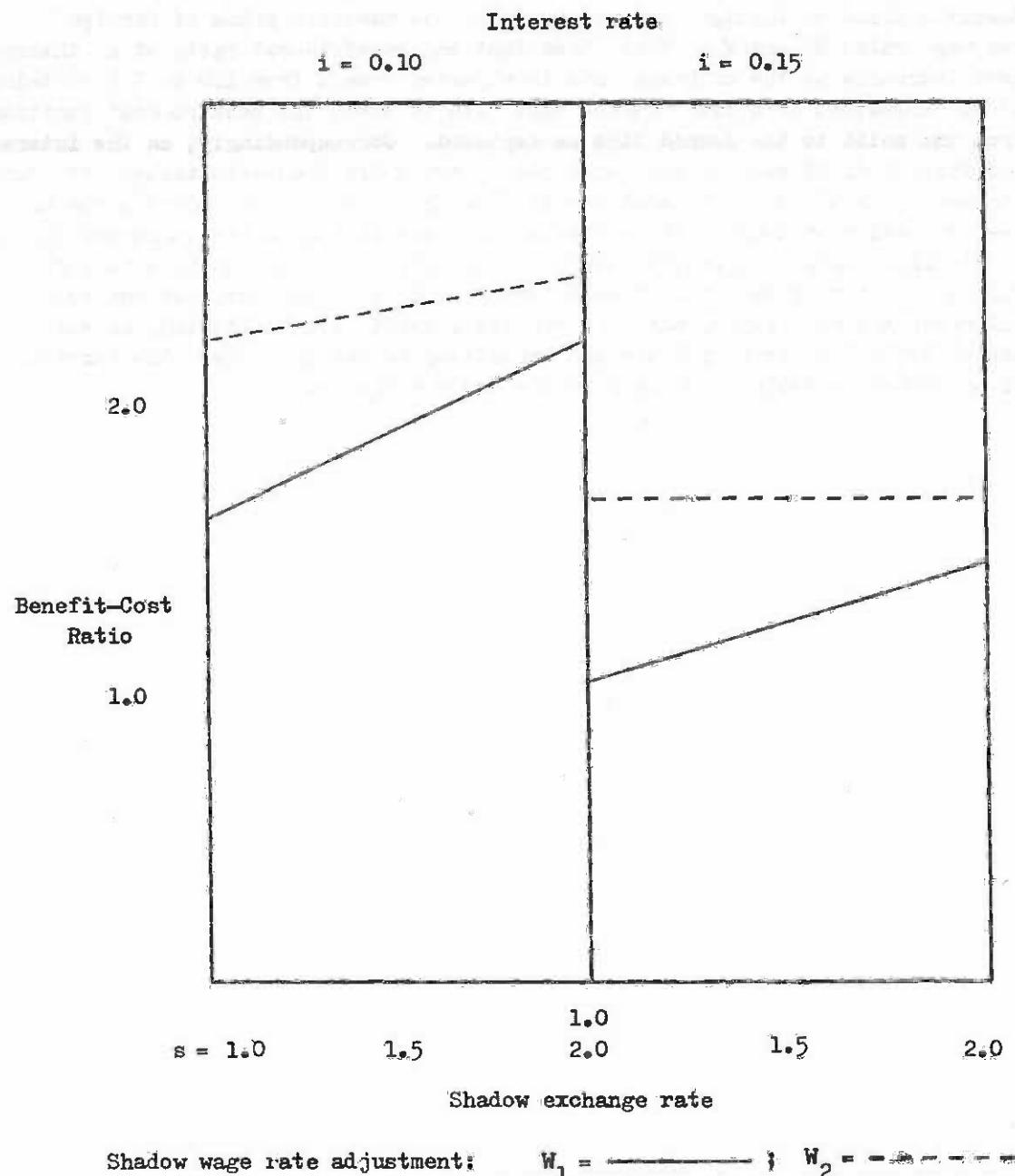
662 Graphical Analysis

Two approaches are recommended in obtaining estimates of the sensitivity of measures of project worth to variations in the prices and technical parameters of a project. The first is to take a rather simple graphical approach as shown in McGaughey and Thorbecke (75), using alternative values of the shadow exchange rate, the shadow wage rate and the project discount rate and examining the variation in the benefit-cost ratio to changes in these variables. A hypothetical example is shown in Figure 1, which depicts the benefit-cost ratio for two interest rates, 10 percent and 15 percent; shadow exchange rate adjustments between one times the domestic price of foreign exchange to twice the domestic price of foreign exchange; and two wage rates W_1 and W_2 . This shows that the benefit-cost ratio at an interest rate of 10 percent increases as the exchange rate is adjusted upward from 1.0 to 1.5 to twice its official value. Likewise, if a lower shadow wage rate is used, the benefit-cost function shifts upward from the solid to the dashed line as depicted. Correspondingly, as the interest rate is increased from 10 to 15 percent the benefit-cost curve drops substantially. At this higher rate of interest, 15 percent, the shadow wage rate and exchange rate adjustments are introduced and as the shadow exchange rate increases, the benefit-cost ratio increases and as the shadow wage rate is reduced, the benefit-cost function shifts upward but to a lesser extent, displaying a "flatter" curve than at an interest rate of 10 percent. Of course, a similar graphical presentation^y may be made for the net present value criterion, as well as the internal rate of return criterion for similar variations in the wage rate, the foreign exchange rate or any other variable of concern to the project analyst.



^y The graphical relationship is likely to be nonlinear.

Figure 1. Sensitivity Analysis, Benefit-Cost ratio



6.3 Shadow Price Elasticity

A second approach is to undertake a quantitative analysis of the sensitivity of an investment indicator, two changes in the shadow price of labour, the shadow price of foreign exchange and the rate of discount. The present example will utilize the benefit-cost ratio (BCR) but the present value criterion can be as easily used. The BCR of any single project may display differing degrees of variation to changes in each of the above mentioned shadow prices. Furthermore, project priorities may be altered substantially by changes in input and output prices. Therefore, in choosing an investment programme it is essential to examine the shadow price sensitivity of each project, because if the benefit-cost ratios vary rather uniformly for all projects, priorities among projects will not change, and if it is found that project priorities and individual project feasibility are insensitive to, say, the wage rate, a smaller proportion of data gathering resources and human talent can be used in selecting this rate.

The benefit-cost ratio is defined

$$BCR = \frac{PV_i(B_t)}{PV_i(C_t)}, t = 0, 1, \dots, n \quad (31)$$

where $B_t = X_t - C_{xt}$ = the project benefits in year t measured in market prices,

X_t = gross output, year t

C_{xt} = variable production operating costs, year t

$C_t = I_t + O_t$ = total project costs in year t valued at market prices,

I_t = investment costs,

O_t = investment operating and maintenance costs,

n = the final year of the project's useful economic life, and

i = the rate of interest.

The BCR of equation (31) is expressed in market prices, so that shadow price adjustments are made by multiplying the corresponding benefits or costs by the ratio of the shadow price of the input (output) to the market price of the input (output). Hence

$$B_t = (fXF_t - XD_t) - (xCF_{xt} + bCB_{xt} + CDN_{xt}) \quad (32)$$

where f is the ratio of the shadow exchange rate to the official exchange rate and b is the ratio of the shadow wage rate to the market wage rate.

Also,

$$X_t = fXF_t + XD_t \quad (33)$$

XF_t = the market value of (traded) exports and import substitutes of the project, year t ,

XD_t = the value of domestic (nontraded) production

$$C_{xt} = fCF_{xt} + bCB_{xt} + CDN_{xt}, \quad (34)$$

where, CF_{xt} = the traded component of the variable input costs

CB_{xt} = the labour component of the variable input costs, and

CDN_{xt} = the balance (domestic non-labour nontraded component) of the variable input costs.

Furthermore,

$$C_t = fIF_t + bIB_t + IDN_t + O_t \quad (35)$$

IF_t = the foreign exchange (traded) component of public investment, year t

IB_t = the labour component of public investment, and

IDN_t = the domestic non-labour nontraded investment costs.

The values of the coefficients f and b are assumed constant throughout the project's life. To initiate the sensitivity analysis of the BCR, limits are placed on the values of the coefficients f and b , and the rate of interest, i , so that $(f_1 \leq f \leq f_2)$, $(b_1 \leq b \leq b_2)$ and $(i_1 \leq i \leq i_2)$. It can be assumed that $f = 1.0$, i.e., the lower bound for the foreign exchange adjustment is the official exchange rate, and $b_1 = 0$ and $b_2 = 1$ since labour is likely to be overvalued at the market wage rate and, at the very limit, its marginal productivity is equal to zero. A wide range of values for i may have to be introduced. The next step is to systematically alter the values of f , b and i and to check the (shadow price) sensitivity of the BCR of each project and the project priorities.

To obtain the desired measure of project sensitivity the concept of the shadow price elasticity of the BCR is introduced. (Again, the concept can easily be extended to the next present value criterion.) The present value of a project's benefits and costs can be viewed as a function of the values of f , b and i . Thus,

$$BCR_{ifb} = PV_{ifb} (B_t) / PV_{ifb} (C_t), \quad t = 1, \dots, T \quad (36)$$

is the ratio of the present value of the benefits of equations (32) to the present value of the costs of equation (35), for a given interest rate, i , shadow exchange rate adjustment f and shadow wage rate adjustment b .

The elasticity of the BCR to a change in the foreign exchange rate is

$$E_f = \frac{\partial BCR}{\partial f} \cdot \frac{f}{BCR}$$

for a given i and b , and since

$$\frac{\partial BCR}{\partial f} = \frac{PV_i (XF_t - CF_{xt})}{PV_i (C_t)} - (BCR) \frac{PV_i (IF_t)}{PV_i (C_t)} \quad (37)$$

it follows that

$$E_f = f \left[\frac{PV_i (XF_t - CF_t)}{PV_i (B_t)} - \frac{PV_i (IF_t)}{PV_i (C_t)} \right] \quad (38)$$

Thus, the elasticity of the BCR to changes in the foreign exchange costs and benefits of the project depends upon the value of the coefficient f and the difference between (1) the ratio of the present value of foreign exchange benefits to the present value of total benefits and (2) the ratio of the present value of foreign exchange costs to the present value of total costs.

The elasticity of the PCR to changes in the shadow wage costs of the project is defined similarly, such that

$$E_b = \frac{\partial BCR}{\partial b} \cdot \frac{b}{BCR} \text{ with } f \text{ and } i \text{ fixed.} \quad (39)$$

It can be shown that

$$E_b = -b \left[\frac{PV_i (CB_{xt})}{PV_i (B_t)} + \frac{PV_i (IB_t)}{PV_i (C_t)} \right] \quad (40)$$

such that the elasticity with respect to the shadow wage is determined by the level of b , (1) the ratio of the present value of variable labour costs to the present value of benefits and (2) the ratio of the present value of the labour component of the public investment costs to the present value of total costs.

Thirdly, the elasticity of the BCR to changes in the interest rate i is defined as

$$E_i = \frac{\partial BCR}{\partial b} \cdot \frac{i}{BCR} \text{ for fixed } f \text{ and } b \quad (41)$$

Specifically, it can be shown that

$$E_i = -i \left[\frac{\sum_{t=0}^T tB_t d^{-(t+1)}}{PV_i (B_t)} - \frac{\sum_{t=0}^T tC_t d^{-(t+1)}}{PV_i (C_t)} \right] \quad (42)$$

where $d = (1 + i)$

The selection of the interest rate is crucial for the feasibility of the capital intensive projects and the feasibility of labour intensive projects is, of course, sensitive to changes in the shadow wage.

Table 14. Shadow Price Elasticity of the BCR to Changes (Δi) in i_{*}

Projects	y	f_b	1.0	2.5
			1.0	0.25
		Δi		E_i
A		5-10%	-1.12	-1.06
		10-15%	-1.63	-1.44
B		5-10%	- .97	- .93
		10-15%	-1.52	-1.26
C		5-10%	-1.17	-1.11
		10-15%	-1.84	-1.54
D		5-10%	-0.84	-0.80
		10-15%	-1.15	-1.09
E		5-10%	-0.95	-0.90
		10-15%	-1.20	-1.13

1/ Based upon eleven irrigation projects cited in McGaughey and Thorbecke (75) such that

A = a large capital intensive project

B = a medium-sized capital intensive project

C = medium-sized moderately capital intensive projects

D = small moderately capital intensive projects

E = small relatively labour intensive projects

Table 15. Shadow Price Elasticity of the BCR to Changes
(Δf) in f , the Shadow Exchange Rate Adjustment

Projects	Δf	1.5	2.0	2.5
		1.0	1.5	2.0
	b	0.75	0.5	0.25
	i		E_s	
A	10	.66	.51	.40
	15	.74	.55	.42
B	10	.06	.02	-.09
	15	.15	.03	-.05
C	10	.17	.08	.01
	15	.27	.15	.05
D	10	.51	.46	.41
	15	.51	.46	.40
E	10	.69	.66	.62
	15	.71	.67	.63

^y See footnote Table 14.

Table 16. Shadow Price Elasticity of the BCR to Changes
(Δb) in b , the Shadow Wage Rate Adjustment.

Projects	f	1.5	2.0	2.5
		0.75	0.5	0.25
	Δb	1.0	0.75	0.5
	i		E_b	
A	10	-0.43	-0.25	-0.13
	15	-0.46	-0.27	-0.14
B	10	-0.45	-0.26	-0.13
	15	-0.51	-0.29	-0.14
C	10	-0.49	-0.28	-0.14
	15	-0.57	-0.31	-0.15
D	10	-0.53	-0.33	-0.18
	15	-0.56	-0.35	-0.19
E	10	-0.49	-0.33	-0.19
	15	-0.50	-0.34	-0.20

^y See footnote Table 14.

As seen in Tables 14, 15 and 16 a project's BCR is not uniformly sensitive to the choice of shadow prices. The elasticity with respect to i , E_i , is greater than (negative) one for most values of f and b ; the BCR is inversely related to i . Furthermore, the higher the rate of interest the greater is the sensitivity of the BCR to changes in i . Shadow wage and exchange rate adjustments alter the elasticity but less than shifts to higher rates of discount. The foreign exchange rate adjustments is uniformly inelastic except for a very high rate of interest at the market wage rate. Subsequent adjustments in the wage and exchange rates reduce the elasticity. Finally, the BCR is positively related to an increasing exchange rate. The elasticity of the BCR to reductions in the shadow wage is likewise inelastic but highly variable ranging from $E_b = - .57$ to $E_b = .13$. Reductions in the shadow wage rate increase the BCR. ^y

For the projects in question it can be concluded that (1) the BCR of any single project is highly dependent upon the combined choice of the discount rate, the shadow wage rate and the shadow exchange rate; (2) the greater is the adjustment in the latter two rates the lower is the sensitivity of the BCR to each; and (3) as the interest rate is increased its effect over the BCR is increased. The selection of the interest rate is crucial for the feasibility of the capital intensive projects and the feasibility of the small labour intensive projects is, of course, sensitive to changes in the shadow wage.

It is recognized that a major difficulty in project appraisal and ranking is the choice of shadow prices to translate private investment choice into social benefit-cost analysis. To this end, the evaluation of the sensitivity of an investment project's feasibility and ranking may yield information which would permit planners to estimate with less urgency the social opportunity cost of a project's input (output). It is suggested that the shadow price elasticity of the benefit-cost ratio provides the desired measure of sensitivity.

In particular, it may be found that the benefit-cost ratio - or any other investment criterion adopted - is relatively insensitive to changes in any one or more of the prices. Among the projects referred to it was found that the BCR displayed varying degrees of sensitivity to the shadow prices. The BCR's of the small labour intensive projects were more sensitive to the shadow wage rate - although with an elasticity less than unitary - than the medium-sized projects. The latter projects, as well as the one large capital intensive project were more sensitive to the choice of the interest rate than the small projects. All projects displayed similar (low) elasticities to the shadow exchange rate, a somewhat unexpected result.

The methodology is general enough to be applicable to any alternative investment criteria - the present value of net benefits, the internal rate of return - and to all classes of investment projects. Both the project's feasibility and ranking among a set of projects can be treated for any assigned limits of the shadow prices.

^y Elasticities are not computed as absolute values so that a negative elasticity reflects an inverse relationship between the direction of the shadow price adjustment and the BCR. In general, this is necessary since it is possible that the sign of the elasticity may vary for a change in the assumed level of the remaining shadow prices which are held constant while computing the own-elasticity.

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ECONOMIC IMPACT ANALYSIS OF FORESTRY PROJECTS:
A Guide to Evaluation of Distributional Consequences
by
Ervin G. Schuster *y*

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1. INTRODUCTION

This paper is designed to serve as a general guide to designing evaluations of the distributional consequences of forestry projects. A model for distributional evaluations will be presented together with some tentative approaches to analysis. Each analyst will need to adapt these recommendations to specific circumstances, since it is impossible to prescribe an analysis model that will be applicable to all situations. For one thing, there is no reason to believe that all decision-makers have the same set of distributional goals and objectives. For another thing, expertise and data will vary with the situation.

As one reads the literature on distributional analysis of forestry projects, it becomes apparent, very quickly, that a set of issues keeps reoccurring. These issues deal with the analytic context within which distributional evaluations take place. They deal neither with why to do the analysis nor with how to do the analysis. Rather, they answer the question: What concepts should the analyst consider when planning the analysis? It is worthwhile to briefly but explicitly discuss some of these — the concept of situational analysis first.

1.1 Situational Analysis

It seems obvious, almost trivial, to assert that the type of distributional analysis conducted should be dictated by the specifics of the situation. What constitutes the situation? Nothing other than the unique nature of the "decision problem" — the decision-maker, the objectives, the alternatives, and the environment within which the decision will be made. The types of variables and the measurements taken on these variables should be determined for each individual decision problem. To the extent that different decision problems share many common aspects — decision-maker objectives in particular — the analysis of distributional consequences can be appropriately similar. To the extent that differences are found, analyses should also differ. In order to be relevant to a decision maker, the analysis should be tailor-made to the specific situation.

While seemingly obvious, the importance of this concept has apparently escaped many analysts. It basically means that there exists no single form of distributional analysis that will have universal applicability. Why? Because the decision problems are not universally identical. Can we expect situational differences to exist relative to distributional analyses? Yes. Differences will exist whenever one encounters differences in economic growth goals and economic development goals from one decision-maker to another. There is no a priori reason to believe that distributional goals for one part of a country will be the same as those for other parts, let alone one nation compared to another. For a distributional analysis to be responsive to the decision-maker's needs, it must be geared to the specific situation.

1.2 Impacts, Adjustments and Geographical Scope

One major difference between efficiency analyses and analyses of distributional consequences is the geographical scope of the analysis. Efficiency analyses do not typically make conscious reference to a geographical area of applicability, dealing exclusively with the existence of costs and revenues. Distributional analyses normally make explicit reference to geographical boundaries. It is important that both the analyst and decision-maker be aware of the implications of geographical limitations.

Whenever an analyst delineates a specific area of land as appropriate for distributional assessments, this necessarily implies that areas outside the borders are analytically irrelevant. A dichotomy exists between the area of concern and the "rest of the world". The area of concern is often termed the "impact area". This may consist of a local community in Mexico, a multi-county area in Montana, a province in Canada, or an entire country. Typically done at an early stage in the analysis, this geographical delineation is critically important because it necessarily controls all subsequent analysis results. Analysts should probably give much more attention to the issue of boundaries. If boundaries are inappropriately drawn, analysis results will also be inappropriate. This is so because many of the tools used in analysis take on meaning in terms of the specific geographical area defined.

Beyond the question of geographical scope lies the issue of "impact". The language used in many distributional assessments would refer to a forestry project as having an impact on employment. But some analysts are extremely hesitant to accept the notion that a forestry project will result in the increase of Y jobs or a decrease of Y wages - the employment and wage impacts. Why is this? The concern is that a redistribution of employment and wages, rather than absolute gains and losses, will actually occur. Considering a specified area only, one argument states that workers released from one activity will simply shift to another line of work. This also can be reversed. No net gain nor loss results, simply shift to another line of work. Given this type of rationale, Waggener (1970) and the Consulting Services Corporation (ca. 1969) prefer the use of the term "adjustment burdens" rather than "impacts". Whether the consequences of forestry projects are reflected in absolute change or simply shifts is a matter lending itself to further analysis.

A final point should be made. Consider the argument stating that if employment opportunities are created that cannot be filled by workers in the geographical area, labour resources will migrate from another geographical area to fill the void. The question is as before: Is there a net gain in local economic activity if one area gains at the expense of another? A decision-maker charged with responsibility of stabilizing all local areas should seriously consider the implications of the dichotomy between "impact area" and "rest of world".

1.3 Data Base Importance

It is difficult to overemphasize the importance of data base in analysis of the distributional consequences of forestry projects. While almost any economic analysis requires data, distributional analyses are particularly sensitive to the existing data base - especially availability of secondary data. This is so because most of the analytical tools are quantitative in nature and generally rely on secondary data. What are secondary data? These data normally consist of numerical information routinely collected and disseminated by public agencies, such as the U.S. Bureau of the Census. Analysts typically rely on secondary sources of data. It is simply too expensive to collect original or primary data. Accordingly, many of the analytical tools discussed later require data from secondary sources for their implementation. In absence of these data, ability of an analyst to conduct an analysis of distributional consequences is seriously impaired -- to the point of infeasibility.

A dilemma is now developing. On the one hand, distributional analyses ought to be geared to the specific needs of a decision-maker. On the other hand, secondary data are required for analytical tools. This guarantees a problem. The analyst may not be able to evaluate certain distributional consequences that are important to the decision-maker. This may be due to either the lack of an analytical tool or lack of needed data. Consequently, analyses are often conducted only in those areas for which both tools and data exist. Except for token treatment, other important consequences are omitted from the analysis. Most distributional analyses are partial analyses, at best.

But the data base is important in other ways. Consider the relationship between available secondary data and definition of the impact area. Many analytical tools require data that describe characteristics of industries within a particular geographical boundary. Some system must usually be devised by which firms are organized into industries to facilitate record keeping. In the United States, the Standard Industrial Classification (SIC) system is the official taxonomic structure and numerical code used by most organizations collecting industrial data (OMB, 1972). For example, SIC 242 is commonly understood as referring to "sawmills and planning mills".

One difficulty with heavy reliance on secondary data organized under any classification system is that the system may not be appropriate. For example, the U.S. system has a category for establishments engaged in production of sheep and goats (SIC 0214). The problem faced by the analyst concerned with these establishments from the standpoint of the range livestock (as opposed to feedlot) is that the distinction simply cannot be made - appropriate codes do not exist. But a more serious problem is that data based on some classification systems can systematically bias analyses. For example, it is relatively easy to make measurements on the timber-using industry under the United States' Standard Industrial Classification system. The system has directly applicable classifications. But what if an economic activity gain in the timber-using industry is associated with a loss in the outdoor recreation industry? No code exists for this latter industry. The problem is that establishments constituting the outdoor recreation industry are subsumed in several (currently unspecified) industrial sectors and therefore cannot be accurately identified. Important decision-making information may be thereby lost.

Another difficulty with heavy reliance on secondary data is the potential for "information disclosure". This may be a problem in some countries and not in others. When present, data collecting agencies are legally prohibited from releasing data on a particular class of industry whereby doing so, some characteristics of a specific firm is revealed (for example, U.S. Code, 1939). Procedures are then established to preclude such revelations. What do disclosure requirements have to do with distributional analyses? This: in order to provide data and yet avoid disclosing information on individual firms, one common remedy is to expand the relevant geographical boundaries. There is a much better chance that data can be released on a specific industry for a multi-county area or a state, as opposed to a single county. The aggregations then dictate boundaries of the local area. There has been noticeable tendency for distributional assessments to focus on the multi-county and state levels. Another way of avoiding disclosure problems is by combining industries, instead of geographical areas. For example, sawmills may be combined with logging, furniture and paper into a wood products industry category. While detailed geographical information may be available, detailed industry information is not. It is, therefore, entirely possible for the data base, and not the decision-maker, to specify both the geographical boundaries and industrial categories used in analysis.

One final aspect of the data base should be discussed. This is the problem where some data available to analysts - particularly income and employment data - are based on "covered employment". This term as used in the United States refers to workers covered by some type of unemployment insurance, either local or national. Non-covered workers and industries are not included in these data. In the case of the United States, omissions include self-employed loggers and others; farmers are almost totally excluded. An associated problem is that definitions change. Definitions as to both industrial classes and "covered" employment can change with time. This is particularly troublesome when interpreting time series data. What appears to be an increase in wages over-time may simply be the result of a change in data collection definitions resulting in more workers being counted; the wages always existed - now they are being recorded. While it is difficult to be aware of changing definitions, it is even more difficult to make appropriate adjustments in analyses.

There are undoubtedly other important data base considerations. Those discussed are illustrative, not exhaustive. The analyst should understand that the results of analysis are strongly dictated by the data used. Where inappropriate or incomplete, the analysis will follow accordingly. The analyst should make every effort to comprehend the data base and its implications for the analysis.

The remainder of the discussion is divided into seven major sections. The next section (2) discusses various evaluation models and recommends a general model. Sections 3 through 7 discuss methods and techniques that can be used to evaluate each component of the recommended model. Examples of techniques and methods will be drawn from a variety of sources available to the author in the United States. This seems preferable to use of comprehensive case studies, since most actual case studies are not particularly comprehensive. The discussion of methods and techniques is not intended to be exhaustive, but rather to provide an overview of the empirical state of the art. Several methods, such as input-output analysis, are themselves the topic of books (see Miernyk, 1965). Detailed treatment is simply beyond the scope of this paper. Several topics are not discussed at all, most notably the goodness or badness of equity implications and intertemporal (or intergenerational) considerations (see Okun, 1975). The topics are of great theoretical, but not empirical, importance. The model recommended is general enough so that it can be adapted to the specific data limitations existing in many countries. The final section provides some concluding remarks.

2. DISTRIBUTIONAL CONSEQUENCES MODELS

Evaluating the distributional consequences of alternative forestry projects is a relatively recent addition to forestry planning processes. Admittedly, much evidence exists that forestry programmes have evolved partly in response to concerns with community stability and other non-efficiency aspects of community welfare (see Waggener 1966 and 1977). But evaluations in this area generally have not been very formal nor explicit. Marty (1975) has recently called for explicit, comprehensive assessments of forestry projects, including distributional consequences. Leven (1970) has recommended a generalized framework for distributional analyses. The following considers selected analysis models directly applicable to forestry.

2.1 Review of Literature ¹

Bentley (1968) was interested in analysis of policy alternatives with regard to U.S. Forest Service timber sales. Relevant policy alternatives included short-term sales, long-term sales, purchaser quota systems and others. These alternatives were evaluated in terms of four aspects:

- (i) Economic efficiency - in terms of maximization of net returns to the treasury from timber sales;
- (ii) Economic progress - regarding long-term growth and development;
- (iii) Economic stability - in terms of employment instability and other social problems;
- (iv) Equity - referring to barriers that distort the distribution of economic opportunity for reasons other than long-term efficiency.

The latter three items relate to the distributional consequences of the policy alternatives. The alternatives were evaluated and compared: a) to a standard and rated as below, equal to, or above the standard, and b) to each other and an ordinal ranking was assigned each alternative relative to the four areas of evaluation. Bentley's model was designed to evaluate timber sale policy, not to serve as a general model of distributional consequences.

Zinn (1972) did attempt to develop a more general model. The objective was to develop a means for analyzing the contributions of forestry to a region. Contributions included both economic and social dimensions. The forestry sector was defined to include a specific set of important forest-based and forest-oriented activities - those concerned with management, production and distribution of wood and recreational resources. Over time this model was refined to entail (Zinn, 1976):

- (i) The amount of economic activity generated in the sector measured by employment, annual payroll and value added in production in the sector;
- (ii) The productivity of the sector - value added per man/hour of production labour;
- (iii) The sector's direct effect on individual welfare in terms of wage rate, vacation credits and pay, annual incomes, social security benefits, health insurance, working conditions and others;
- (iv) The sector's effect on regional economic stability - turnover of enterprises, permanency of employment, etc.;
- (v) The sector's effect on the geographic distribution of economic activity over the region;
- (vi) The sector's interactions with the public sector;
- (vii) The sector's effect on the distribution of income in the region;
- (viii) Characteristics and conditions of entrepreneurship in the sector including legal structure of enterprises and the quality or performance of entrepreneurship in the sector;
- (ix) The sector's generation of external costs and environmental impacts;
- (x) The secondary economic effects of the sector.

¹ As mentioned, this review is limited to United States literature.

While the model was originally intended to deal with the present contributions of forestry to a region, it could serve as the basis for an analysis of distributional consequences of forestry projects. It is comprehensive.

Convery(1973) attempted to develop a model for measuring local economic impacts of forest management practices by the U.S. Forest Service in the southern part of the United States. This model was to be: a) inexpensive, b) easy to implement, c) universally applicable, and d) intellectually defensible. Convery eventually focused on the following effects:

- (i) Income - where value added defined as value of gross output less cost of material inputs was selected as a first measure of income generated;
- (ii) Employment - where man-years was used as the measure of employment quantity and quality of employment was assayed by examining wage rates, seasonality of employment, and physical work conditions;
- (iii) Tax revenue - where the U.S. Forest Service revenue sharing programme with local governments as "payments in kind" were measured for each management alternative.

To further enhance application of this model, a computer programme was written to accomplish the necessary calculations (Field and Convery, 1976). This programme, BENEFIT, provides forest planners with information after they enter appropriate data at local computer terminals.

2.2 The Approach of This Paper

Recently, Schuster (1976b) developed a model to evaluate the distributional consequences of alternative timber harvest schedules. This model calls for evaluation of distributional consequences in the following areas: a) economic activity, b) individual welfare, c) area equilibrium, and d) local government. The model was based on availability of methodology, availability of data, and a desire to promote more comprehensive evaluations. The framework is applicable in evaluations of a wide range of forestry projects, not just scheduling of timber harvest. As such, it is being used in a more general way by the U.S. Forest Service (1977). This model will be presented later.

All of the models discussed deal with major categories of distributional consequence - stability, employment and individual welfare. These represent the areas of distributional consequences with which the analyst will work. But these areas cannot be measured directly. For example, we cannot directly measure "equity". Each area must be defined in terms of something that can be measured. And then the analyst must select a specific unit of measurement. Thus, before going on, we should adopt some common terms, not only to better communicate, but also to indicate the several decisions an analyst must make when planning an evaluation.

A comprehensive analysis of a forestry project has several parts. For example, one part may deal with environmental consequences, another with distributional consequences and a third with efficiency. Call this the "type" of consequence. What aspects of each "type" should be evaluated? The answer will be specified in terms of the "classes" of consequences within the "type" that will be evaluated. In terms of earlier discussion, stability and individual welfare would each be a class within the distributional consequences "type". The analyst must then define each class of consequences in terms of one or more "indicators". Consider the class of distributional consequences dealing with individual welfare. There exists several different indicators of welfare change - wage rates, home ownership, and disposable income are but a few. Since consequences associated with any given class may be diverse, it seems appropriate to use several indicators. This is particularly important since the indicators need not give consistent signals. For example, employment levels and value-added levels each may serve to indicate one aspect of the level of economic activity. It is perfectly reasonable to speculate that in some cases value-added may increase while employment level declines. Is economic activity going up or down? Is it good or bad? Answers require major value judgments best left to the decision-maker, not the analyst (Davis and Bentley, 1967). The analyst would be well advised to provide both types of information to the decision-maker. One step remains: each indicator must be measured or quantified. Some variable must actually be specified. For example, in the case of employment level, the analyst may choose to use "annual average employment of the 'covered' labour force over sixteen years of age", or some other measurement variable.

Figure 1 shows the hierarchical nature of the elements in any model to evaluate the distributional consequences of forestry projects. It is less important for the reader to accept the terms used in the hierarchy - types, classes, indicators - than to accept the notion that a hierarchy exists. This is important because the relationship between the analyst and the decision-maker varies along the hierarchy. What is the basis for identifying "types" of analysis of forestry projects? The decision-maker's goal structure defines the "types". What is the basis to determine "classes" of distributional consequences? The decision-maker's goal structure also defines them. What is the basis for identifying "indicators" of economic activity? The theoretical and empirical expertise of the analyst mixes with the needs of the decision-maker to specify appropriate indicators. What is the basis for identifying measurement variables? Enter the analyst. This area is almost exclusively the domain of the analyst. But importantly, the relationship between the analyst and the decision-maker is seen to vary along the hierarchy. This approach to analysis will help ensure maximum usefulness of the analysis in the decision process. Other approaches based on providing decision-makers with information they "ought to know" (determined exclusively by the analyst) will likely be found inappropriate and/or irrelevant. The analyst must function within the information needs of the decision-maker.

The remainder of this paper will proceed on the basis of a rather generalized model of distributional analysis. Table 1 shows this model in terms of classes and indicators. The ones shown may be applicable to many situations, inapplicable to others. But the main advantage of this format lies in its utility as a framework within which methods and techniques can be discussed. In applying this model, the first step involves definition of the economic setting and baseline data to be used in evaluating each class of consequence.

Figure 1. Hierarchy of elements in a distributional consequence model

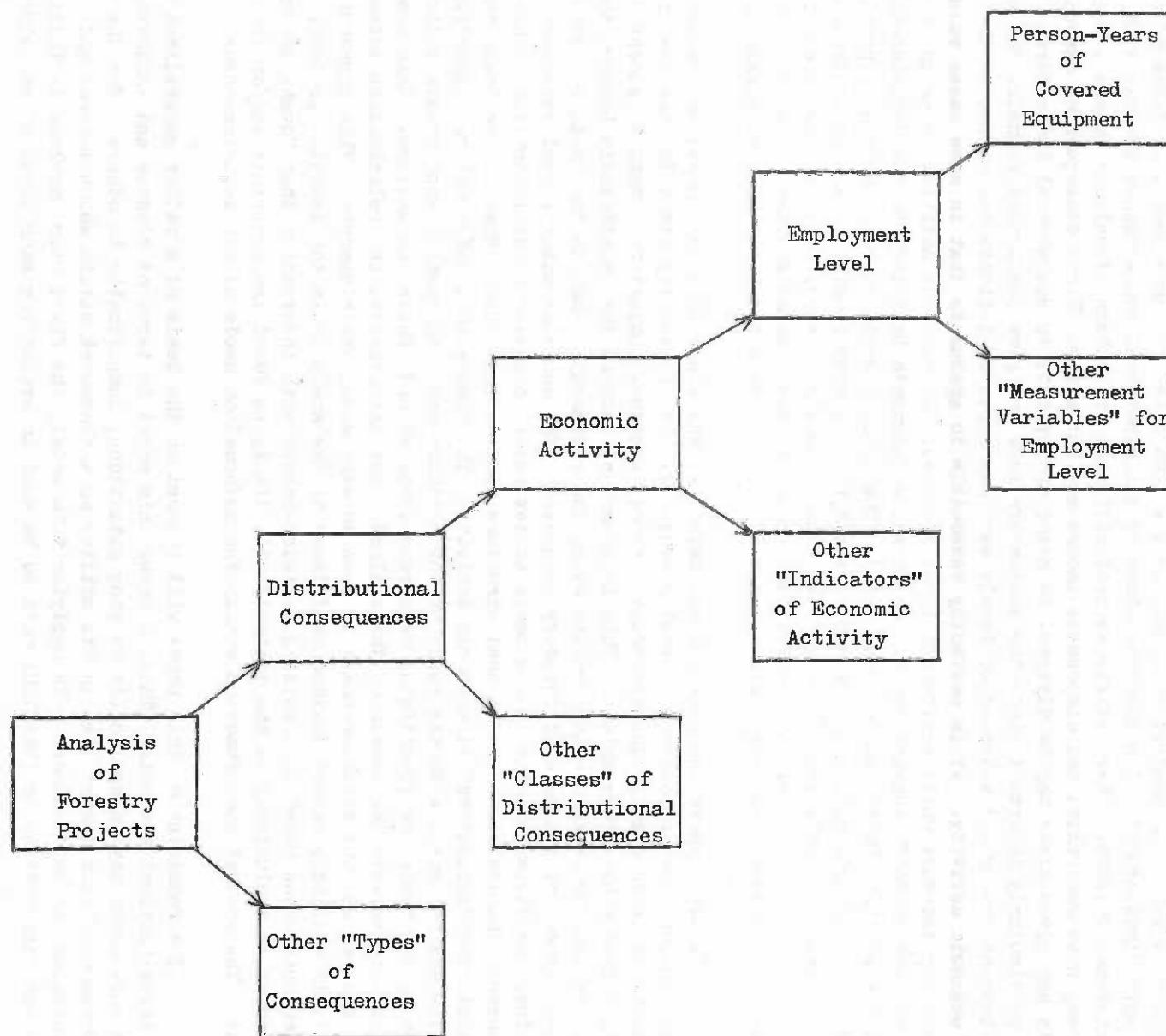


Table 1. Classes and Indicators of Distributional Consequences for Use in Evaluating Alternative Forestry Projects

Class of Consequence	Indicator of Area
Economic activity	Employment Payroll/Wages/Earnings Value added Sales
Individual welfare	Unemployment rate Average wage rates Income redistribution
Area equilibrium	Economic diversity Community adjustments
Local government	Intergovernmental payments Cost to local government

3. THE ECONOMIC SETTING - BASELINE DATA

One of the most important areas of information to provide a forestry decision-maker is a description of the existing socio-economic environment in the geographical area of concern. This could be considered the first step in any analysis of distributional consequences of forestry projects. The goal of this effort should be to provide enough of the right kinds of information to give the decision-maker a "feel" for the geographical area of concern. The existing environment provides the setting within which the forestry project will function. Without this knowledge, it would be difficult to gauge the desirability of any proposed project which will change the environment.

But description of the economic setting is also essential to the analyst, for two other reasons. First, since the distributional analysis should always be geared to economic change resulting from the proposed project, the status quo must be identified. The analyst must assess the status of an economy "with" and "without" the effects of the proposed project. Knowledge of the current situation will help the analyst make the "without" project assessment. The recommended "with" and "without" analysis may be contrasted to a "before" and "after" analysis. They are not the same, the difference mainly being that economies are constantly undergoing change, quite apart from forestry projects. A "before" situation does not reflect this change. Assessment of an economy "without" the forestry project is recognition that the effect of the project is the difference between two states of change, one with and one without the forestry project (Bell, 1976). Second, knowledge of the existing economic setting is essential to interpreting or understanding the implications of a

distributional analysis. Too many distributional analyses are sterile, presented as facts and figures only. Suppose an analysis determined that a forestry project would result in employment of one hundred additional persons in the wood products industry. The long-term implications of additional employment in an area of chronic unemployment may be quite different than in a more "healthy" economy.

A question immediately arises: what constitutes the geographical boundaries of the project area? The answer can be reasonably simple or very complicated. On the simple side, just ask the decision-maker. Two types of responses are likely. First, the answer may be given in terms of some combination of political units (counties, districts, states, provinces, or regions). For some reason - possibly because of political pressure, possibly because of a previous study that delineated impact areas, possibly because of organization policy - the decision-maker may be able to specify the area of concern. From the analyst's view, this response is the easiest to handle. Simply carry out the analysis for the specified area. If the answer does not correspond to political boundaries - for example, watershed boundaries - the analyst will likely encounter data problems. Data generally available for analysis are compiled on the basis of political boundaries. Desirable or not, practical necessities of analysis will likely compel a political boundary delineation of the project area.

Alternatively, the decision-maker might respond: "Do the analysis for the area that is affected by the forestry project." This means the analyst must do some preliminary work before actual analysis can start. The analyst must somehow select a delineation for the area. Two general approaches may be used: a) use existing, delineated boundaries, or b) develop other relevant boundaries. Depending on availability of existing data, the analyst may well find that someone has already identified aggregations of political units that are homogeneous with respect to economic structure. For example, the U.S. Department of Commerce has delineated Standard Metropolitan Statistical Areas (SMSAs) and Bureau of Economic Analysis (BEA) Economic Areas; the U.S. Water Resources Council has delineated Water Resources Regions and Subregions. The analyst should select one such region delineation system based on its correspondence with the forestry project being evaluated and availability of subsequent analysis data. Once a regional system is selected, the analyst simply identifies that region containing the forestry project and then uses it in analysis.

While use of an existing system to delineate the area of concern has the distinct advantage of expediency, it has a disadvantage. The delineation may not be exactly appropriate - too big or too little in terms of the project being analyzed. The analyst may have to delineate the boundaries. How? On the one hand, the analyst could conduct a rigorous, special study to define the boundaries (for example, see Fox and Kunar, 1966; and Bouderville, 1966). But since this may well require more resources and time than available for most project analyses, sophisticated approaches to identifying the region will not be discussed further here. Rather, the analyst will probably adopt a less rigorous approach. Any number of information sources may be used. Officials or colleagues may be consulted. Availability of data may be assessed in relation to the project being considered. For example, if a project that will eventually result in a timber harvest change is being considered, the analyst may decide to restrict consideration to those political units (e.g. counties or provinces) containing the sawmills that will process the harvested timber.

By one way or another, the analyst must determine the boundaries of the area to be studied. It is this area then for which a description of the economic setting or environment will be developed.

What economic aspects of the area should be described? There is no general answer, only a recommendation. The analyst should describe those economic aspects that are: a) important to the decision-maker, b) necessary for the "without" part of the distributional analysis, and c) useful to the analyst in interpreting other results of the analysis. Nevertheless, some generally applicable items can be identified. The following list of socio-economic characteristics was adapted from that used as the basis to develop an overview of the population and economic activity in several planning areas of the U.S. Forest Service's Northern Region (USFS, 1975):

Population

- levels over time
- distribution by age, race and sex
- change components including births and deaths
- density and crowding
- migration patterns
- future projections

Employment

- levels by industry
- distribution by occupation
- opportunities
- labour force participation and unemployment

Income

- per capita and family
- distribution
- cost of living
- welfare statistics

Others

- housing
- family stability
- freedom from crime
- educational achievements
- health of people

The listing above is illustrative only. The analyst will have to add and subtract from the list depending on the circumstance being evaluated. Obviously, not all of the analyst's effort could be devoted to describing the existing situation. How much effort should be devoted? Again, there is no general answer; the analyst's judgement is required. Presumably, this judgement will be based on the relationship between the cost of providing additional information and the value of that additional information in decision-making. Before considering the next topic, Table 2 presents an example outline of a rather comprehensive description of an economic setting. Once an adequate description of the economic setting has been developed, the remainder of the distributional analysis can be pursued.

Table 2. Example: Outline of comprehensive description of economic setting

BEAVERHEAD NATIONAL FOREST
SOCIO-ECONOMIC OVERVIEW FOR UNIFIED PLANNING

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Source: USFS, 1974.

4. IMPACTS ON ECONOMIC ACTIVITY

Consider now the first class of consequences shown in Table 2. Distributional consequences of forestry projects can be measured and reflected in many ways. But the dominant way - and typically the only way - is to show these consequences in terms of changes in the level of economic activity. Note again that the analyst should be concerned with measuring change resulting from (or attributable to) the project. The goal of this effort should be to measure aggregate, net change in economic activity. The word "aggregate" is used because a forestry project may require inputs from supporting economic sectors; concern is with all sectors. The word "net" is used because any particular forestry project may have negative effects on some other forestry or non-forestry sectors. The most obvious example of this is where forestry projects compete for a fixed budget; expansion of one aspect (e.g. recreation) can only be done at the expense of restricting another (e.g. timber). In this event, the analyst should identify the total net project effects as the sum of two parts, one positive and the other negative.

Measurement of changes in economic activity requires the analyst to have some knowledge of the underlying relationship between inputs and outputs - the production function. Figure 2 shows that all stages in a production activity require use of economic resources. The typical economic efficiency analysis evaluates the relationship between the value of inputs and outputs over time.^y This phase of the distributional analysis measures the levels of economic activity associated with the production process.

What indicators of economic activity should the analyst consider? The possibilities are many. But in practice only a few are used and, of these, only one or two may actually be measured. The listing below shows the four commonly evaluated indicators of economic activity.

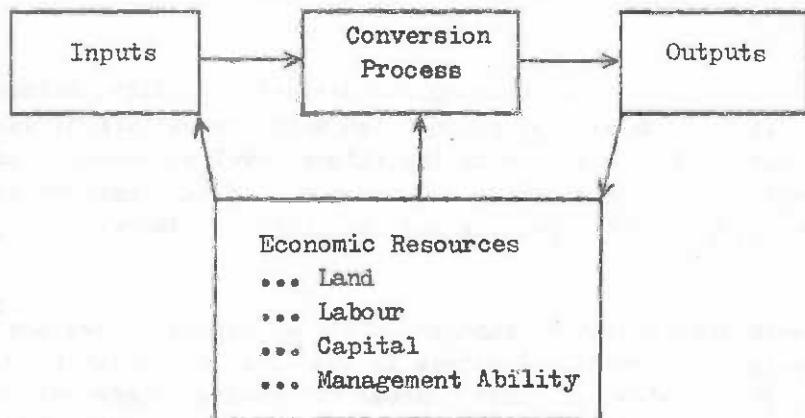
- (i) Employment levels - Changes in the level of total employment in various industrial sectors should be determined on a full-time basis. That is, employment should be couched in terms of "person-years". Part-time and seasonal employment must be converted to an annual equivalent. The analyst must be aware of the distinction between "total" and "covered" employment. If the distinction is great, the analysis results should be modified as appropriate.
- (ii) Payroll and wage levels - This generally refers to income of workers in the local economy. Again, aggregate and sector data should be developed. The analyst should be aware of definitional problems. Depending on the data source used, earnings, income, payroll and wages will likely be different and have different clientele-based meanings. An important difference may involve wages and earnings. While "wages" often refers to payments to employees, the term "earnings" additionally includes payments to proprietors.
- (iii) Value added - On a local basis, this indicator of economic activity is analogous to gross national product. It measures value or worth added to a product by industrial activities. It is the total of all differences between sales-receipts and costs of intermediate goods. As a measure of total income generated, its biggest limitation for local area analysis is that some of this income (profits and interest payments) may go to economic units outside the local area (Convery, 1973).

^y See Economic Analysis of Forestry Projects (EAFP), FAO Forestry Paper No. 17.

(iv) Sales levels - This amounts to the value of gross output or aggregate retail sales. It is part of the data needed to make value-added calculations. One major difficulty with this indicator is that it typically only registers market transactions.

Which one or combination of these indicators should be evaluated? The empirical literature certainly does not help answer the question. All, either singly or in combinations, can be found. Experience, however, suggests that decision-makers can more easily comprehend changes in employment and wage levels, than value-added or sales. The analyst should seriously consider use of more than one indicator. This is because changes in economic activity need not be consistent between indicators. A forestry project may be associated with an increase in wages and a decrease in employment. Both should be provided to the decision-maker.

Figure 2. Hypothetical Production Process



4.1 Primary Impacts

Once the analyst selects an indicator(s) of economic activity to evaluate, the next step is to link the forestry project to a change in that economic activity. This task will require the analyst to use either existing relationships or to develop needed relationships. Skill, ingenuity, and imagination may be required. The analyst must first relate the forestry project to changes in commodity outputs. The listing below shows some potential output measures. In all cases, the output measure used should be: a) related to a traditionally accepted unit of output measurement and b) capable of being translated into one of the indicators of economic activity change discussed earlier.

(i) Timber - timber harvest change measured in board feet, cubic feet, cubits, or cubic metres;

- (ii) Water - water yield change measured in acre-feet or cubic metres per hectare;
- (iii) Recreation - recreation activity change measured in terms of the opportunity to generate occasions, visitor days, or recreation days;
- (iv) Range - forage or range livestock production change measured in animal unit months or grazing or animals produced;
- (v) Wildlife - wildlife population change measured in terms of population level or population density.

Two illustrations of approaches to this problem may be useful. First, Ferguson and Phillips (1975) estimated the effect on total sales associated with changing a recreation area to a national park. Data indicated that the 1 562 000 visitor days of recreation in 1975 were associated with US\$58.6 million of expenditures by recreationists. They then developed a series of projections for change in the level of recreation activity associated with establishment of a national park. After accounting for normal growth, they identified the levels of total sales in the region associated with each projection level. Second, Johnson (1972) determined that there were approximately six wood products workers per million board feet of timber harvested in Montana. After adjustments were made, it was determined that a change of 100 million board feet in timber harvest would result in a change of 500 jobs.

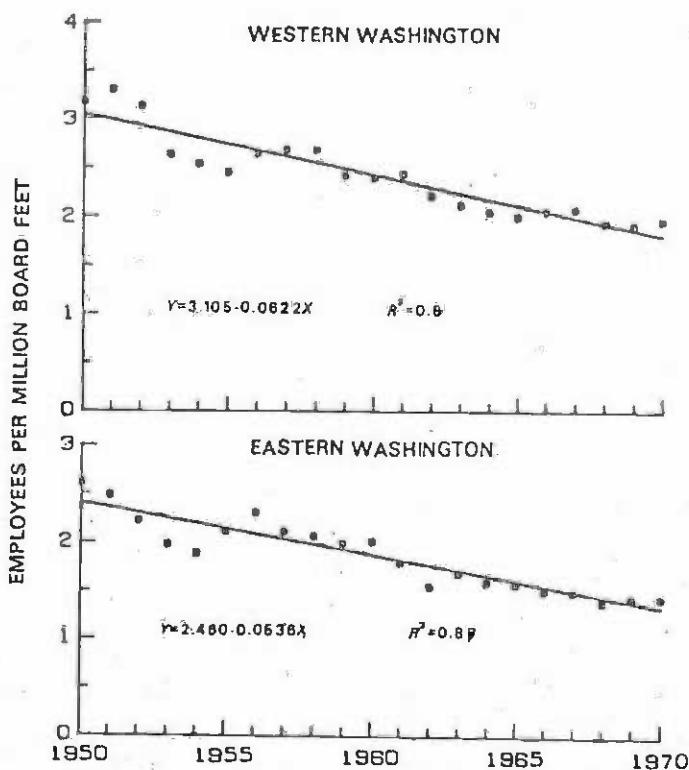
It should be clear from the above examples that one overriding assumption is usually implied: linearity. It is usually assumed that the existing pattern of commodity output relative to economic activity will determine the future level of economic activity. Technically speaking, constant returns to scale are assumed. If this assumption is realistic with regard to the forestry project, results are meaningful. Otherwise, adjustments must be made.

Forestry projects that result in changes in timber harvest level are so common that further elaboration seems appropriate. A change in the level of timber harvest will have a first-order effect on those industries that consume or process roundwood. These industries are referred to alternatively as the timber-using industry, the wood-products industry, or the forest-products industry. Whatever the term used, no standard definition or description exists. Analysts appear to generally adopt one of two approaches: a) the narrower approach which includes only processors of industrial roundwood, and b) the broader approach which includes secondary processors, such as furniture plants. For the purpose of most distributional analyses, the narrower approach is more practical since secondary processors do not generally use forestry outputs directly and will eventually be included as part of "aggregate impacts".

In general, measures for primary impact indicators regarding timber harvest take the form of relationships involving employees or dollars of wages per million board feet of timber cut in a particular area. In the example mentioned earlier, it was estimated that about six wood-products workers per million board feet of timber harvested were employed in Montana (Johnson, 1972). These measures are sometimes called consumption ratios. They can be made more refined or sophisticated by taking changes over time into consideration, and by taking the geographical pattern of timber-origin and processor-destination into consideration.

The first two refinements can be illustrated by work in the Pacific Northwest (Wall and Oswald, 1975). Figure 3 shows estimates of employment consumption ratios based on time-series data. The equation resulting from fitting these data to some curve form is used to estimate future ratios. For example, if an analyst desired the appropriate ratio for target date 1975, that date would be entered into "X" and the equation shown solved for 1.55 employees per million board feet; note: "X" = (target date) - (1950). As a second refinement, the authors developed equations for several industrial classes; the multiplier above is applicable only to the logging industry. For these types of ratios to be useful, the analyst must be able to estimate the change in timber volume reaching, for example, western Washington. Timber source is an open question.

Figure 3 - Average annual employment in logging (SIC 2411)
per million board feet of wood harvested in
Washington by state area, 1950-1970



Source: Wall and Oswald, 1975

How does one construct consumption ratios? The following is the procedure outlined by Wall and Oswald (1975):

To develop ratios for use in predicting employment impacts of changing material supplies, we need a historical base of employment and raw material consumption data. Employment data are generally available from state employment security departments. Raw material consumption data are often difficult to come by. We were able to get raw material consumption data for logging and pulping. However, for lumber and plywood manufacture, we had to develop consumption estimates based on historic production levels. We used recent production-consumption ratios to develop the estimates of consumption for the historic time series. This process assumes static utilization of raw material and possibly could result in an understatement of raw material use and, consequently, an overstatement of employment requirements in the early years of the time series data. The effect of this possible bias is not known, but we feel it is nominal and does not substantially affect the relationships developed in this paper.

Since the technique of employment prediction through these ratios is generally used to determine impacts of changes in resource supply, it should be used for those industries whose operations in the area of concern will be affected by resource supply changes in that area. These include the primary resource oriented manufacturing processes: logging, lumber manufacture, plywood manufacture, and conversion of wood fiber into pulp and paper stock. The ratios should not be used for typically secondary manufacturing industries, whose location is due to market, or other non-raw material considerations.

The factors that determine the level of labour input in the production process tend to change over time in most industries and most areas; consequently, the ratio of employment to raw material consumption in the production process also tends to change over time. If a trend can be identified for such ratios - that is, if we can identify the direction and rate at which they change over time - then we can extrapolate the identified trend into the future to predict employment required per unit of raw material consumed in the production process. This approach, of course, assumes that the aggregative effects of the changes in the underlying factors which have resulted in the historical trend in employment - consumption ratio(s) will continue into the future.

The employment-consumption ratios used in projecting employment levels should, if possible, be developed from data for the area of concern. For instance, if projections are being made for a county, use of ratios developed for large areas, such as the half-state areas presented later in this report, could be quite inappropriate and misleading. In case of insufficient data in a small area, ratios from a broader area can be used if it can be determined that they are similar to those for the smaller area.

Some of the curves, if extended for many years, will indicate an employment-consumption ratio approaching or reaching zero employees per unit of wood consumed. This is unrealistic. In such cases the curves should be extrapolated for only short periods into the future. When extrapolations for longer time periods are required, the user must temper the curves based on the best available evidence and expert opinion of what the employment-wood consumption relationships will be like in the future.

Finally, any one of several curve forms may adequately fit the historical trend data. The potential user is then faced with making a selection. It is often expedient to select the simplest form that adequately defines the trend. But in this as well as other aspects of selection and use of ratio trends for projection of employment in the forest products industries, considerable judgement is required for the user.

An alternative set of procedures has been outlined by Bell (1977). These approaches follow, one being quick and inexpensive and the other more costly and time consuming:

Using Published Data

Step 1. From the equations presented in Wall and Oswald (1975) for Oregon, we get the following ratios for employees per million board feet.

<u>Industry</u>	<u>Ratio</u>
Logging	1.46
Sawmills & planning mills	3.49
Veneer and plywood	6.44

Step 2. From ... Oregon or local forest data, we get the distribution of the national forest harvest.

<u>Industry</u>	<u>Volume (mm bd.ft.)</u>	<u>Percent of Total</u>
Sawmill, planning mills etc.	322 914	77
Veneer and plywood	96 089	(23)
Total	419 003	100

Step 3. Assuming changes in harvest will be distributed to the mills in the same proportion as the present harvest, we derive a combined employees per million board-foot ratio:

$$1.46 + 0.77 \times 3.49 + 0.23 \times 6.44 = 5.63$$

(logging) (sawmills) (veneer) (ratio)

In some cases, employment for pulpmills may also be added if they absolutely depend on the local residues from the veneer and sawmills for wood input. Generally, they have alternative wood supplies so that pulp production and thus employment will probably not change with changes in local harvest.

Using Original Data

Step 1. From a survey of individual mills, determine the average annual consumption of wood and average annual employment. Divide the number of employees by the amount of wood used to get the average employment-wood-consumption ratio for each mill such as is shown in the fictitious example below.

<u>Firm</u>	<u>Ratio</u>
Average of eight local loggers	1.5
Silesia Milling Co.	3.0
Sidney Scrag Mill	2.1
Porter Veneer and Plywood, Inc.	8.6

A better procedure if the data can be obtained is to calculate the marginal rather than the average employment-wood consumption ratio. This could be obtained by observing the effect on employment of year-to-year changes in mill inputs, assuming no change in technology. Or it could be arrived at by asking the mill operator how employment would change with a given change in his wood supply.

Step 2. Estimate the proportion of increase or decrease in harvest going to each mill. This could be done on the basis of past harvest or it could reflect mill bidding power or the type of raw material involved. For the example, we will assume a decrease in the number of large logs will prevail.

<u>Firm</u>	<u>Past harvest (percent)</u>	<u>Anticipated harvest (percent)</u>
Silesia Milling Co.	30	40
Sidney Scrag Mill	20	20
Porter Veneer and Plywood, Inc.	50	40

Step 3. Apply the same principles as in the previous step 3.

$$1.5 + (0.4 \times 3.0 + 0.2 \times 2.1) + 0.4 \times 8.6 = 6.6 \\ (\text{logging}) \qquad \qquad \qquad (\text{sawmills}) \qquad \qquad \qquad (\text{veneer}) \qquad \qquad \qquad (\text{ratio})$$

The third modification takes the relationship between the origin and destination of timber into account. Table 3 is based on official planning regions in Idaho (Schuster, Koss and Godfrey, 1975). All timber-using industry employment is aggregated. The focus of concern for the analyst is the location of timber harvest. For example, each million board feet of timber harvest in Region I was associated with 5.53 people employed in Region I, 0.31 in Region II, and no employ in the other regions - that is, timber was not delivered from Region I to Regions III-VI.

While several difficulties exist with use of consumption ratios, they do represent about the best measures available to quantify primary economic activity impacts regarding timber. The indicator used need not be employment. Any indicator - wages, employment, or sales - for which data are available will work. If the results are interpreted as relative indications, rather than absolute truths, misuse will be minimized.

Table 3. Timber harvest and employment in Idaho's timber-using industry, by planning region, 1972

Region of Timber Harvest	1972 Timber Harvest	Idaho State Planning Region of Timber Destination						Total 1972 Direct Employment
		Region I	Region II	Region III	Region IV	Region V	Region VI	
Region I	610.42	5.53	0.31	0.00	0.00	0.00	0.00	3,565
Region II	811.67	0.51	6.53	0.29 (0.23) ^a	0.00	0.00	0.00	5,950
Region III	207.61	0.00	0.07	15.26 (11.95)	0.11 (0.06)	0.00	0.00	3,206 (2,508)
Region IV	13.43	0.00	0.00	0.05 (0.04)	17.08 (9.90)	0.00	0.00	230 (133)
Region V	18.83	0.00	0.00	0.00	0.00	1.81 (0.74)	0.00	34 (14)
Region VI	96.45	0.00	0.00	0.75 (0.59)	0.00	0.00	5.76 (5.50)	628 (587)
Imports ^b	93.72	5.30	0.53	0.65 (0.51)	0.00	0.00	0.00	607 (594)
Totals	1,852.13							14,219 ^c (13,302)

- a. Counties with employment but receiving no timber were excluded from calculations; multipliers, where different, are shown in parentheses: these multipliers are similar to county multipliers.
- b. Imports were estimated from unpublished data obtained in the Idaho Forest Industry Study.
- c. Due to rounding errors, this total does not agree with the actual totals of 14,223 and (13,305).

Source: Schuster, Koss and Godfrey, 1975.

This section will be concluded with an example (Table 4) that deals with calculation of primary wage and employment impacts of a 10 million board feet decrease in timber harvest in southwestern Oregon. Primary economic impacts are reflected in the logging, plywood and sawmill industries.

Primary economic impacts should be calculated for every distinct aspect of the forestry project and then combined into a total of primary impacts. Accomplishing this, the question remains: What are the aggregate impacts of the forestry project on economic activity?

Table 4. Example: Calculation of primary employment and wage impacts

Let 10 million board feet now be subtracted from the allowable cut of that portion of the Umpqua in Douglas County. The new level of allowable cut is 347.0 million board feet annually. What are the probable economic impacts or adjustment burdens regarding Douglas County? There will be impacts. The following will discuss these under the four major impact classes described earlier.

Economic Activity. Given the state of economic activity in Douglas County, how will a change in allowable cut be reflected? The first consideration involves the relationship between allowable cut and actual cut. It seems clear from Table 25 that an allowable cut reduction would be directly translated into lower actual cuts. Of the five indicators recommended, two will not be evaluated. Since costs and gains regarding other outputs are assumed to be constant, they will not be evaluated. Additionally, data are not currently available to adequately evaluate changes in value-added. To show the effect of timing on impact evaluations, target years 1970 and 1976 will be used where useful.

How will the decrease of 10 million board feet of timber harvest be distributed among the timber-using industries of Douglas County? Sales between the Forest Service and timber-using industries (Darr and Fight, 1974) suggest the relationship below. If the harvest change were allocated on the basis of percent

<u>Industry</u>	<u>Sales</u>	<u>Percent</u>	<u>Harvest</u> (mmbf)
Logging	US\$ 425,152	4.1	- 0.41
Plywood	8,409,481	80.3	- 8.03
Sawmills	<u>1,637,734</u>	<u>15.6</u>	<u>- 3.56</u>
	10,472,367	100.0	-10.00

sales, the 10 million board feet would be distributed as above.

One way to determine primary impacts on employment and wages is to follow the methodology outlined by Wall and Oswald (1975). The following shows the employment-consumption ratios for the industries of concern. These ratios are

<u>Industry</u>	<u>Equation</u>	<u>Consumption ratio (Y)</u>	
		<u>1970</u>	<u>1976</u>
Logging	$Y = 1,748 - 0.012$	x 1.4900	1.4132
Plywood	$Y = 14,6011 - 0.4969$	x 4.6631	1.6817
Sawmills	$Y = 7,832 - 0.2135$	x 3.5620	2.2810

expressed in terms of employment per million board feet. While the linear form expressing ratios was used, log forms are also available. When the calculated ratios are applied to timber volumes, the following employment and wage levels result. The 1970 wage changes were based on prevailing industry wage rates (USDC, 1971). The 1976 wage levels used rates that assumed the same proportionate increase occurring between 1970 and 1973 would occur to 1976.

<u>Industry</u>	<u>Employment</u>		<u>Wages</u>	
	<u>1970</u>	<u>1976</u>	<u>1970</u>	<u>1976</u>
Logging	- 0.61	- 0.58	- 4,410	- 5,349
Plywood	- 37.44	- 13.50	- 298,472	- 176,985
Sawmills	<u>- 5.56</u>	<u>- 3.56</u>	<u>- 43,268</u>	<u>- 41,367</u>
	- 43.61	- 17.64	- 346,150	- 223,702

Source: Schuster, 1976b.

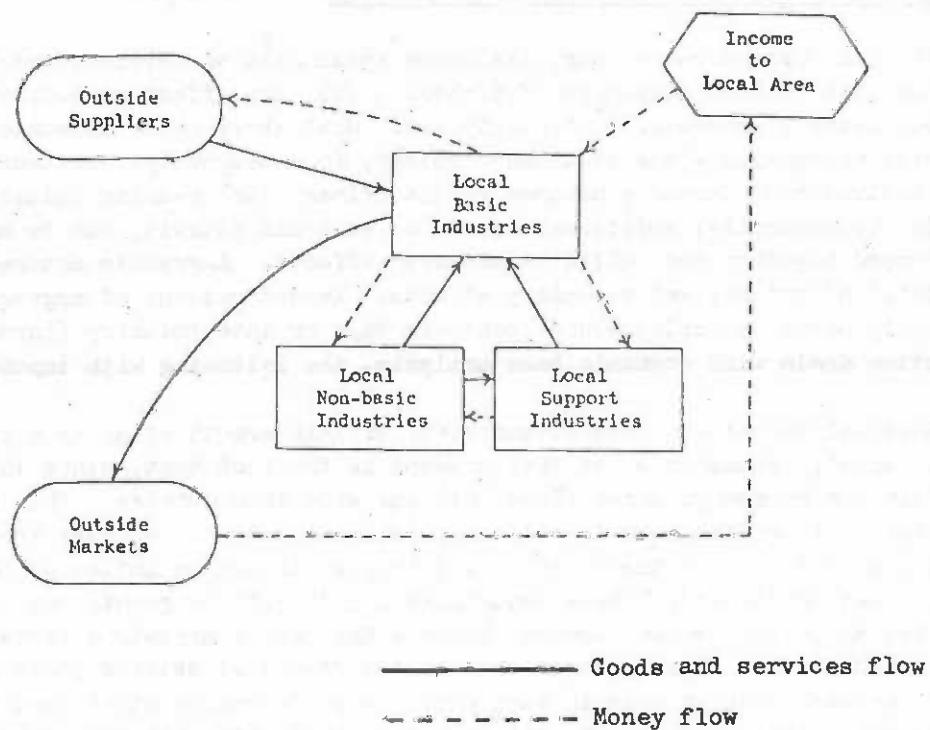
4.2 Aggregate Impacts - Economic Base Analysis

The consumption ratios just discussed speak only to levels of employment or wages associated with primary consumers of timber. Will the effect on economic activity stop with these primary processors? Probably not. What about other economic activity associated with timber processing - the equipment dealers, food bought by woods workers and other support activities? Income generated in the primary timber-using industry is spent and re-spent. Consequently, additional rounds of economic activity can be envisioned; these can be lumped together and called "secondary" effects. Aggregate change in economic activity is the total of primary and secondary effects. Investigations of aggregate impacts on economic activity normally employ either economic base or interindustry (input-output) analysis. This section deals with economic base analysis, the following with input-output analysis.

Regional scientists have attempted to explain growth of an area in terms of its "economic base". Fundamental to this concept is the fact that, since local areas do not print their own currency, money flows into the area from outside. This normally occurs when markets outside the area demand and purchase goods and services produced internally. Firms that export most of their output and thereby create an inflow of money to the area are classified as "basic". These industries are "basic" to growth and development of an area. They are often termed "export" because they serve markets outside the area. Figure 4 shows that the income flowing to an area is the result of selling goods and services to "export" markets. This income in turn partly goes to paying other local industries for necessary goods and services. Sometimes these other local industries are lumped into a class called "non-basic" and sometimes they are split into "non-basic" and "support" industries. The output of "support" industries are inputs needed in the productive process of the basic industries. For example, a fertilizer industry may provide a necessary input to a timber growing industry that exports its output. Local "support" industries thereby substitute for outside area suppliers. The "non-basic" industries (food stores, barber shops) then provide the goods and services needed to maintain other aspects of the basic industries. In all likelihood, most industries lie along a continuum between completely basic (all income received from outside the area) to completely non-basic (all income received from inside the area).

We should emphasize here that the source of income is important. It is not necessary for output to be exported, but rather for income to be imported. In most cases, these concepts will not be in conflict. In the case of recreation, however, the distinction is important, for recreation commodities are often produced and consumed locally. This industry is "basic" then to the extent that recreationists from outside the region come to the region and spend money earned from outside the region. In this circumstance, the income is effectively imported but the output is not exported.

Figure 4. Role of basic industries in an area's economy.



Growth of an area's basic industry is associated with changes in income receipts from outside areas. Changes in other activities (non-basic) are merely the result of overall change in the basic industries. The multiple effect on economic activity is measured by the "economic base multiplier" (Barkley and Allison, 1968). The essential concept underlying any economic base multiplier is that increases in any exogenous variable (e.g. basic industry income or employment) are magnified by other transactions that occur within the area. The area's income or employment is increased by a multiplied amount because of the re-spending that occurs within the area as a result of income received from sales of goods and services produced in the area, but sold outside the area. Multiplier analysis then is relevant and appropriate for analyzing impacts if, and only if, the industry being altered is part of the area's economic base.

Calculation of an economic base multiplier (EBM) is relatively straightforward.^{1/} The economic base multiplier is applicable to any indicator of economic activity (employment, wages, sales, etc.) for which an appropriate data base exists. The EBM is simply the ratio of total economic activity to economic activity in the economic base. Consider an income multiplier. If the proportion of total income re-spent in an area is "r", the total impact of a change in export income in the area is:

$$\Delta Y = (1 + r + r^2 + r^3 + r^4 + \dots + r^n) \Delta Y_B = \left(\frac{1}{1-r} \right) \Delta Y_B$$

^{1/} For an excellent discussion of multiplier interpretation, see Coppedge and Youmans (1970).

where:

r = the proportion of each dollar that is re-spent within the region by residents ($0 < r < 1$)

ΔY_B = change in basic industry income

ΔY = change in area's income

n = spending round

Let "r" be replaced by (Y_N/Y) where Y_N is non-basic industry income ($Y_N = Y - Y_B$). The economic base multiplier then becomes:

$$\begin{aligned} EBM &= \frac{1}{(1 - Y_N/Y)} \\ &= \frac{1}{1 - (Y_N/(Y_N + Y_B))} \\ &= \frac{Y}{(Y_N + Y_B) - Y_N} \\ EBM &= Y/Y_B \end{aligned}$$

The multiplier is applied:

$$\Delta Y = EBM (\Delta Y_B)$$

If the economic base multiplier were calculated to be 1.65, then an income change of \$1 000 in the basic industry would be associated with a \$1 650 income change in the total area ($\$1 000 \times 1.65$). Of the \$1 650 change, \$1 000 is associated with the basic industry and \$650 with the non-basic industries.

The fundamental problem in economic base analysis is determining which industries constitute the economic base. Various approaches have been articulated by Hoover (1971), Convery (1973) and Tiebout (1962):

- (i) Definition - Examine each sector individually, and determine whether it is basic or non-basic. For very small economies this approach can to some extent be justified because most of the sectors will either export almost all of their output or fulfill a clearly local supportive role. For a small, rural area using this method, agriculture, mining and manufacturing would be classified as basic, while all of the rest (including construction) would be categorized as non-basic. However, even at this level there are some sectors which are both basic and non-basic; as the economy gets larger these joint sectors are more likely to be found.

(ii) Location Quotients - To separate the basic from the non-basic employment in an industry, the use of a location quotient has been advocated. The employment identified with the portion of the coefficient greater than one is classified as "export". Implicit in this approach is the assumption that local patterns of use and habits of consumption are the same as average national ones. Locations quotients will be discussed shortly.

(iii) Minimum Requirements - To overcome this latter problem, Ullman *et al* (1971) developed what they call a minimum requirements approach. They take all of the cities in a particular size class, and determine the proportion of the total work force in each city employed in each sector of the economy. The lowest percentage for each sector from all the cities is designated as the "minimum requirements" percentage for that sector for cities in this size class. By regressing these minimum requirements (Y) against population (X), parameters (a) and (b) can be determined for:

$$Y = a + b \log X$$

The best estimate of total minimum employment requirement (non-basic employment) is given by this equation.

(iv) Direct Measurement - Given sufficient funds, export industries can be measured directly. Methods available fall into two groups: a) direct measurement of commodity and dollar flows by means of various data sources and b) surveys through interviews and questionnaires of consumers and firms.

Use of location quotients has received much attention in forestry circles, and warrants further discussion. Location quotients (sometimes called the coefficient of localization) are quantitative indexes based on a comparison of economic activity in the industrial sectors of an area to a larger, regional or national system. The listing below shows the hypothetical percentage distribution of employment in industries for a local area and a larger area.

<u>Industry Class</u>	<u>Employment in Local Area</u>	<u>Employment in Larger System</u>	<u>Location Quotient</u>
X	.60	.20	3.0
Y	.30	.40	.75
Z	.10	.40	.25
<u>Total</u>	<u>1.00</u>	<u>1.00</u>	

Location quotients are calculated by dividing an area's percentage for an industry by the larger system's percentage for that industry. A location quotient in excess of 1.0 is normally accepted to identify an export or basic industry. The percentage distribution of any economic activity (wages, employment, etc.) can be used to calculate location quotients. Once calculated, the analyst may simply define basic industries to be those which have values in excess of 1.0 for the location quotient. The logic in this approach is that once specialization exists, production predominately serves export markets.

The analyst may use the data above to go to the next step. In the case of employment, estimate "excess employment". Upon reflection, the location quotient will be found to reflect an area's economic specialization. The overall degree of specialization may be determined by subtracting the area's percentage distribution of employment, by industry, from that of the larger system. Where an area's percentage exceeds the larger system's percentage, it is termed "excess"; employment in that industry is in "excess" of national or regional requirements. In this event, only that portion of economic activity associated with the "excess" is included in the economic base. The listing below shows that excess employment levels are calculated from the same data base as location quotients.

Industry Class	%		%		Excess Employment
	Employment in Local Area	Employment in Local Area	Employment in Larger System	Excess	
X	600	.60	.20	.40	400
Y	300	.30	.40	-.10	-
Z	100	.10	.40	-.30	-
Total	1 000	1.00	1.00	.40	

In the case of the location quotient, the percentages are divided while to calculate excess, they are subtracted. This latter approach argues that both internal and external markets are served on a basis proportional to the degree of excess.

Opportunities to critique and extend the several methods available to estimate size of the economic base abound. Others have undertaken this effort (see Isserman, 1977; Mathur and Rosen, 1974; and Tiebout, 1962).

Where does one obtain the data necessary to conduct an economic base analysis? The answer depends on the approach adopted. If an analyst had detailed knowledge of an area's economy, the analyst could simply define, identify or otherwise list the basic industries. However, this method is risky since it relies on the analyst's impressions of reality; these may not be correct. Alternatively, a specialized study of firms in an area could be conducted to determine the amount of export income associated with each firm. But even with these approaches, the analyst will probably have to research secondary data sources to determine levels of total economic activity. These secondary data sources are the primary source of information for the location quotient, excess employment, and the minimum requirements approaches to defining the economic base.

Once the analyst determines a numerical value for the economic base multiplier, accurate estimates of primary impacts become very important. Estimates of primary impacts provide the driving force behind economic base multipliers - that is, if these primary impact industries are part of the economic base. To determine aggregate change, the analyst multiplies the primary change by the multiplier. Calculation of aggregate change is shown in Table 5 that follows, for a complex forestry project. While the economic base approach is reasonably common and inexpensive, a methodologically dissimilar approach to aggregate impacts exists - input-output analyses.

Table 5. Example: Calculation of aggregate impacts with economic base multipliers

THE IMPACT AREA

Using the criteria outlined earlier, the local impact area was identified for the Hiwassee Unit; Bradley, Polk, Monroe and McMinn Counties were included (see fig. 1). Detailed ten year plans (1970-1980) dealing with population, the economy, land use, transport systems and housing are available for Bradley and Polk counties (Tennessee State Planning Commission, 1971a, 1971b), while plans are in preparation for the counties of McMinn and Monroe.¹⁾

The area is one with a record of modest but consistent economic growth centered mainly around Cleveland, Tennessee, the "growth point" of the area. Growth in the manufacturing and mining expanding from 14548 in 1960 to 22291 in 1970 (Table A). Median family income in 1969 was \$ 7101, 4.8 percent below the figure for the state, while 18.25% of all families were classified as being below the poverty level, compared with 18.2 percent for the state (Bureau of the Census: General Social and Economic Characteristics).

Table 1. Employment in the Hiwassee Sub-Region^{1/}, 1960 and 1970

Year	Agric., For. & Fisheries	Basic Manuf. & Mining	Total No.	Non-basic Other	Total	Total basic
1960	3974	14548	19522	17659	36181	1.95
1970	2141	22291	24432	22409	46841	1.91

^{1/} Counties Bradley, McMinn, Monroe and Polk.

Sources: Census of Population 1960: General Social and Economic Characteristics Tennessee: Census of Population 1970 ibid.

IMPACTS MEASURED

The outputs of the Hiwassee unit are listed in Table B. Basic employment generated by each of these alternatives must first be determined, and then the multiplier can be applied to determine non-basic and total employment. Payroll and value added data per employee can be derived and applied to the employment estimates.

Table 2. Annual Outputs from the Hiwassee Unit under each Management Alternative

Mgmt. Alt.	Wood (MBF)			Recreation (Visitor Days) ^{2/}			
	Saw-logs	Pulp-wood	Total ^{1/} value(s)	Developed	Dispersed	Hunting	
Present	2786	1984	97587	7500	14214	10386	6150
1	2925	2084	102459	7875	15635	10178	6460
2	2692	1917	94293	8250	15635	10905	6765
3	1388	988	48616	20010	16346	11425	6150
4	2773	1976	97135	8250	14924	10905	6460

^{1/} Using the average price received over the past 3 years, 1970, 71, 72; \$32.25/M.B.F. for sawlogs and \$3.9/M.B.F. for pulpwood.

^{2/} Visitor day means 12 hours of recreation use by one person.

Source: U.S.F.S. Southern Regional Office (1971b). Unit plan for Management of the Hiwassee Unit, Cherokee National Forest, p. 27.

Table 5 (cont.d)

NON-BASIC AND TOTAL IMPACTS

By applying the multiplier (1.91, from Table 1) total and non-basic employment can be derived (Table 12 and Figure 2a). Payroll per employee in the non-basic sector is derived as the state-wide weighted average of annual employee payroll in the selected services, construction, wholesale trade and retail trade sectors, and works out at \$4453 for 1967 1/. Non-basic and total payroll can now be displayed for each alternative (Table 12 and Fig. 2b).

Table 12. Basic Non-Basic and Total Employment (E) and Payroll (P) Generated by each Management Alternative, Hiwassee Unit.

Alternative	Basic			Non-Basic			Total	
	E No.	P \$	V.A. \$	E No.	P \$	E No.	P \$	
Present	91.6	453349	736254	83.4	371380	175.0	824729	
1	96.4	477474	784241	87.7	390528	184.1	868001	
2	90.8	477935	715820	82.6	367818	173.4	815753	
3	63.3	303841	367780	57.6	256493	120.9	560334	
4	91.4	451849	727426	83.2	370490	174.6	822339	

Source: Table 11.

Table 11. Total Basic Employment (E), Payroll (P) and Value Added (V.A.)^{1/} Generated by each Management Alternative, Hiwassee Unit

Alternative	Management					Wood		
						Processing		
	E No.	P \$	EE No.	P \$	V.A. \$	E No.	P \$	V.A. \$
Present	10	70,000	16.3	59413	113268	50	271956	622986
Alt. 1	10	70,000	17.1	62330	118828	53	289747	665413
Alt. 2	10	70,000	15.7	57226	109100	48	263604	606720
Alt. 3	10	70,000	8.1	29524	56287	25	135978	311493
Alt. 4	10	70,000	16.2	59049	112573	49	267780	614853
Recreation								
					Total			
					E No.	P \$		\$
Present	15.3	51980			91.6	453349	736254	
Alt. 1	16.3	55397			96.4	477474	784241	
Alt. 2	16.8	57105			90.8	447935	715820	
Alt. 3	20.2	68339			63.3	303841	367780	
Alt. 4	16.2	55020			91.4	451849	727426	

1/ With the limitations noted in the text.

Sources: Tables 4, 5, 10

Source: Convery, 1973.

4.3 Aggregate Impacts - Input-Output Analysis

Input-output is one of the most powerful descriptive and analytical tools available to the analyst evaluating distributional consequences of a forestry project. Also called "interindustry analysis", it belongs to the general family of "activity analyses", which also includes linear programming. The nature and degree of interdependence among producing and consuming sectors of an economy is basic to input-output analysis. Analysis of the linkages between sectors in an economy is not new in economics, Quesnay and Walras undertaking such efforts over a century ago. Yet modern efforts dealing with input-output analysis can be traced back only a few decades to the work of Wassily W. Leontief and development of high speed electronic computers.

Input-output analysis can be used in two major ways to evaluate forestry projects. First, it can determine the level of output in all industries of an economy that will be just sufficient to satisfy total demand of forestry products. Second, it can be used to assess the changes in output of various industries in an economy associated with a change in supply of inputs from the forestry sector. These efforts can be accomplished by means of a set of multipliers, somewhat similar to the economic base multipliers previously discussed. This section will briefly review input-output analysis and its application to forestry projects.

Input-output analysis is basically an accounting system that describes dollar or volume flows of commodities between all sectors of an economy. Each sector not only produces goods and services consumed by other sectors but is also a consumer itself, purchasing goods and services to be used in its production process. Data used to describe these linkages are often based on empirical, statistical estimates - typically reflecting one point in time. As such, input-output tables are only as good as the data upon which they are based. Although often used to predict future economic structures, input-output is inherently a "static" model representing a "snapshot" of an economy at a point in time.

The Input-Output Table - A complete input-output analysis basically develops and uses three types of tables. The first table constructed can be called the Input-Output Table - alternatively this can be called the "dollar flow" table or "transactions" table. This table shows the flow of goods and services (measured either in volume or value) among industrial sectors of the economy. Figure 5 shows that each industry appears twice, once as a producer of output and once as a consumer of input. The elements of each row show the amount of a given industry's output that was used by every other sector to produce their own output, and how much was bought by the final consumer. The rows show the distribution of the output, the "market mix", for each industry, summing to total output. The elements of each column show the source of each industry's input of raw materials, semi-finished products and services bought from various supplier industries. Columns show the pattern of input purchases made by a given industry. With some exceptions (the primary input row, the final demand column and the total output column), for every row there is a corresponding column. These rows and columns amount to an itemization of input and output of each designated producing and consuming industry.

Figure 5. Sample Input-Output Table

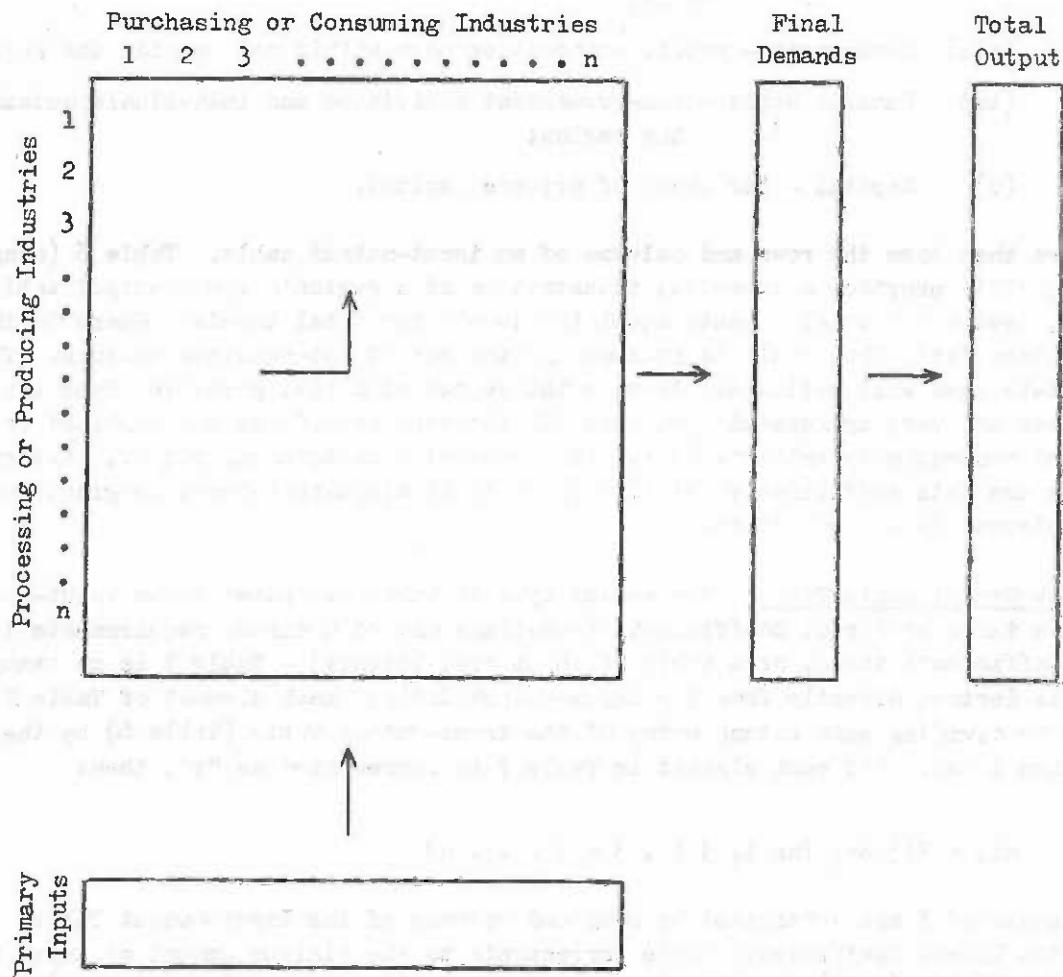


Figure 5 shows a distinction between consuming industries (also called intermediate demand industries) and final demand, similarly between processing industries and primary inputs. When these distinctions are made the input-output model is termed "open". If the final demand and primary input sectors were included as producing and consuming industries along with other industries, the model would be called "closed". Since most analyses concerning forestry are "open", the following discussion will apply to the "open" model.

What sectors are included in an input-output table? Hoover (1971) has identified five major, fundamental sectors:

- (i) Intermediate - private business activities within the region;
- (ii) Households - individuals and families residing or employed in the region;
- (iii) Government - public authorities both within and outside the region;
- (iv) Outside World - non-government activities and individuals outside the region;
- (v) Capital - the stock of private capital.

These sectors then form the rows and columns of an input-output table. Table 6 (adapted from Hoover, 1971) provides a numerical illustration of a region's input-output table. As can be seen, levels for total outputs equal the levels for total inputs. Where do the forestry sectors fit? They would be included in the set of intermediate sectors. The underlying data base will ultimately dictate the degree of detail possible. Some input-output studies are very aggregated such that all forestry activities are combined or even subsumed (and consequently unidentifiable) in a general manufacturing sector. Alternatively, some studies use data sufficiently detailed so as to distinguish between logging, sawmills and other relevant forestry sectors.

Direct Coefficients Table - The second type of table generated in an input-output analysis is a table of direct coefficients (sometimes called a direct requirements table, technical coefficients table, or a table of input coefficients) - Table 7 is an example. This table is derived directly from the Input-Output Table. Each element of Table 7 is constructed by dividing each column entry of the Input-Output Table (Table 6) by the corresponding column total. Let each element in Table 7 be represented as "a", then:

$$a_{ij} = X_{ij}/X_{*j} \text{ for } i, j = 1, \dots, n$$

where the levels of X are determined by rows and columns of the Input-Output Table. Each element of the Direct Coefficients Table corresponds to the minimum amount of input from each producing sector (rows) in order to generate one unit of value (e.g. dollar) or output in the purchasing sector (columns). In this example, Industry D requires 19 cents worth of input from Industry A, 12 cents from Industry B, 27 cents from Industry C and 19 cents from itself in order to generate \$1.00 worth of output. Consequently, coefficients in each column equal 1.0 when summed. The sum of the coefficients in each row has no economic meaning.

Table 6. Sample input-output table

		PURCHASING				SECTORS			
						Final Demand		Sectors	
		Intermediate Sector, by Industry				Households (Consumer Goods Sales in Region)	Government (Sales to Government)	Outside (Exports)	Capital (Gross private investment including additions to Inventories Output Totals)
		A	B	C	D				
Intermediate processing sector, by industry:	A	300	400	100	500	1600	500	200	700 4300
	B	50	200	1000	300	100	200	100	900 2850
	C	1000	200	100	700	100	300	200	500 3100
	D	0	800	200	500	700	0	0	400 2600
<u>Primary input Supply sectors</u>									
Households (Labour Services)		1900	300	1000	400				
Government (Public Services)		200	100	200	100				
Outside (Imports)		200	300	300	0				
Capital (Capital consumption and withdrawals from inventories)		650	550	200	100				
Input Totals		4300	2850	3100	2600				

Table 7. Sample Direct Coefficients Table

Processing Sector	Purchasing Sector			
	A	B	C	D
A	.07	.14	.03	.19
B	.01	.07	.32	.12
C	.23	.07	.03	.27
D	.00	.28	.07	.19
Primary Inputs:	.69	.44	.55	.23
Total	1.00	1.00	1.00	1.00

A Direct Coefficients Table can be immediately useful to the analyst of forestry projects. Assume the listing below represents the direct coefficients of the sawmill sector. Suppose the sawmill sector increased its sales of lumber outside the region by one million dollars. In order to do this, it must increase purchases from the construction sector by \$600 (.0006 x \$1 000 000), from the logging sector by \$291 700, from the transportation sector by \$26 000, and so forth. The direct effect on other industry sectors can be thereby determined. These direct effects get translated into employment and wages in these support industries. Do the effects of increased lumber sales now stop with these industries? No. In order to produce \$291 700 of additional output, the logging sector must increase use of its supply inputs. This generates another round of purchasing, which in turn generates another round. The summation of all subsequent rounds of economic activity generated by increased lumber sales is called "indirect effects".

Producing Sectors	Purchasing Sectors	
	Sawmills	Others
Construction	.0006	.4488
Logging	.2917	.0000
Sawmills	.0923	.0900
Transportation	.0260	.4212
Primary Inputs	.5894	.0400
Total	1.0000	1.0000

Direct and Indirect Coefficients Table - The aggregate or total effect (direct and indirect) of a change in final demand for an industry sector is shown in a table of direct and indirect coefficients - alternatively called total requirements table, direct and indirect requirements table, total direct and indirect effects table, inverse coefficients table and the Leontief inverse table.

Given the information provided in a Direct Coefficients Table, the analyst could conceivably calculate the effect of each additional round of spending discussed above, and then total all such calculations. Fortunately, this labourous task can be accomplished much more simply by use of matrix algebra. Development and use of this technique is generally attributed to Wassily W. Leontief. Information contained in the original Input-Output Table and the Direct Coefficients Table are used to implement this procedure. Let "X" represent the vector of total outputs and "Y" represent the vector of final demands (summed) for the processing sectors shown in an Input-Output Table. Let "A" represent the matrix of coefficients for each processing sector shown in a Direct Coefficient Table. Total output can then be expressed in matrix notation as:

$$X = AX + Y$$

The listing below shows these matrixes using the data provided in Tables 6 and 7:

$$\begin{bmatrix} 4300 \\ 2850 \\ 3100 \\ 2600 \end{bmatrix} = \begin{bmatrix} .07 & .14 & .03 & .19 \\ .01 & .07 & .32 & .12 \\ .23 & .07 & .03 & .27 \\ .00 & .28 & .07 & .19 \end{bmatrix} \cdot \begin{bmatrix} 4300 \\ 2850 \\ 3100 \\ 2600 \end{bmatrix} + \begin{bmatrix} 3000 \\ 1300 \\ 1100 \\ 1100 \end{bmatrix}$$

In matrix notation, the vector of final demand (Y) can be expressed:

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

where I is an identity matrix. This system of numbers is shown in the listing below:

$$\begin{bmatrix} 1000 \\ 0100 \\ 0010 \\ 0001 \end{bmatrix} = \begin{bmatrix} .07 & .14 & .03 & .19 \\ .01 & .07 & .32 & .12 \\ .23 & .07 & .03 & .27 \\ .00 & .28 & .07 & .19 \end{bmatrix} \cdot \begin{bmatrix} 4300 \\ 2850 \\ 3100 \\ 2600 \end{bmatrix} + \begin{bmatrix} 3000 \\ 1300 \\ 1100 \\ 1100 \end{bmatrix}$$

In the language of input-output analysis, the expression $(I-A)$ is called the Leontief Matrix.

Elements of the Direct and Indirect Coefficients Table are defined by the elements of the Leontief Inverse Matrix, $(I-A)^{-1}$. This matrix is used to solve for total output:

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

Table 8 shows the results of this matrix inversion process for the data described and as shown in Tables 6 and 7. Table entries, excluding totals, correspond to the Leontief Inverse Matrix. Each entry in the table represents the total output, direct and indirect, required from each of the processing sectors necessary for a one dollar increase in final demand of the purchasing sector. The column total in the table represents the combined effect. This total is called either the "total output multiplier", or the "final demand multiplier", or the "business multiplier".

Table 8. Sample Direct and Indirect Coefficients Table

Purchasing Sector	Purchasing Sector			
	A	B	C	D
A	1.12	.29	.16	.36
B	.13	1.23	.44	.35
C	.30	.28	1.17	.50
D	.07	.45	.25	1.40
Total	1.62	2.25	2.02	2.61

Using our earlier example of sawmills and lumber sales, the listing below illustrates the direct and indirect coefficient for the sawmill sector.

Producing Sector	Purchasing Sector	
	Sawmills	Others
Construction	.0012	1.095
Logging	.3587	.000
Sawmills	1.1198	.250
Transportation	.0367	.928
Total	1.5164	2.273

If sales of lumber outside the region were to increase by one million dollars, changes in the value of output in producing sectors associated with this would eventually amount of \$1 200 in the construction sector, \$358 700 in the logging sector, \$1 119 800 in the sawmill sector, and \$36 700 in the transportation sector. Summing all, the total increase in output value would be \$1 516 400. One useful way of visualizing this change (Goldman and Nakazawa, 1974) is to disaggregate the total change into components:

Total Multiplier Effect	Initial Economic Change	Initial Economic Effect	Secondary Economic Effect
• (\$1 516 400)	= (\$1 000 000)	+ (\$410 600)	+ (\$105 800)

Where: a) the initial change is due to the increased lumber sales; b) the initial economic effect represents the proportion of additional internal inputs required by the sawmill sector to satisfy the increased sales level (sum of direct coefficients between sawmill sector and producing sectors shown earlier (.4106 = 1.0 - .5894) times the change in sales level); and c) all subsequent adjustments in the economy needed to satisfy increases in the internal purchases by the sawmill sector.

Wage and Employment Impacts: In many instances, change may be more meaningfully reflected in terms of employment, wages or earnings. The analyst may either modify original matrix calculations or adopt a procedure that uses final demand multipliers (FDM) and some additional information. A reasonably straightforward procedure has been recently outlined (BEA, 1977).

Consider the change in wages or earnings first. Given an Input-Output Table (such as Table 6), the analyst can quickly identify gross output (GO) for a specific industry. Next, either wages or earnings for the industry being analyzed must be determined. Since wage or payroll data are more commonly available from secondary data sources than are earnings data, the following focuses on wages. Simply calculate the wage/gross output ratio for the industry in question ($E_j = W_j/GO_j$). However, since the total gross output change applies to all industries, E_j cannot be applied to the total change. This expression must be modified before change in total wages can be determined. The quantity " e_j " must be calculated as follows:

$$e_j = (1/FDM_j)(E_j) + (1 - 1/FDM_j)(E^*)$$

where FDM_j is the final demand multiplier for industry j , E_j is as before, and E^* is a total wage/gross output ratio for the nation or region. The change in total wages can then be calculated:

$$\Delta \text{ Total Wages} = (\Delta GO_j)e_j = \Delta FD_j(FDM_j)(E_j)$$

where ΔFD_j is the change in final demand for the industry in question. In this case, the wage multiplier is:

$$WM_j = FDM_j(E_j)$$

The wage multiplier could then be used as was the FDM to assess the consequences of a change in final demand. If earnings are used instead of wages, these data simply replace wage data in all calculations.

Using the final demand multiplier for the sawmill sector (j) developed earlier, the following illustrates a wage multiplier calculation:

if ... $FDM_j = 1.5164$
if ... $E_j = \text{wages/gross output} = .239$
if ... $E = .3$
then ... $e_j = (1/1.5164) .239 + (1 - 1/1.5164) .3$
= .260
then ... $WM_j = 1.5164 (.260)$
= .394
if ... $\Delta FD_j = \$1\ 000\ 000$
then ... $\Delta \text{Wages} = (\Delta FD_j)(WM_j)$
= $1\ 000\ 000 (.394)$
= $\$394\ 000$

Determination of employment change only requires knowledge of the employment level and the level of total wages for the region. These, again, can be obtained from secondary data sources. Calculate the ratio of total employment/total wages (TE/TW). The change in employment is then calculated:

$$\Delta \text{Employment} = \Delta \text{Wages} (\text{TE}/\text{TW})$$

For example, using the past illustrations:

if ... $\text{TE}/\text{TW} = .0001$
then ... $\Delta \text{Employment} = \$394\ 000 (.0001)$
= 39.4

Forward and Backward Linkages: The most common way of using input-output analysis is to evaluate changes in any economy that result from increased sales in final demand. For example, the analyst might increase final demand for output of the sawmill sector and then tract the impacts this would have on other sectors as well as the economy in total. Because this approach essentially works backward from final demand in a specific sector back into the economy, these economic impacts are called "backward-linked". It is particularly useful in analyzing situations including product market or demand forces. However, another situation can exist: supply modification. Waggener (1972) illustrates this point:

If we assume that the level of timber harvesting is reduced within a particular community, our traditional analysis will trace the consequences backward through the equipment supplier, the logging contractor, the sale of gasoline to the logging truck driver, and the related indirect consequences ... But is this the end? There is certainly reason to believe that it is not. As you know, those logs went someplace - perhaps to the mill on the edge of town ... The change in timber supply in this case spills "forward" into the primary producing sector ... this forward impact leads to substantially larger impacts than would the backward effect considered above.

Economic impacts based on supply considerations are termed "forward-linked". Recognizing the distinction between demand and supply constraints, Darr and Fight (1974) calculated a backward-linked multiplier of 1.88 and a forward-linked multiplier of 7.53 for Forest Service timber sale activities in Douglas County, Oregon.

There are two general approaches that can be used to determine forward-linked effects. The first involves manipulation of the Input-Output Table (Hoover, 1971). Earlier, a table of direct coefficients was calculated where each of the elements was defined:

$$a_{ij} = X_{ij}/X_{\cdot j}$$

These could be termed "input coefficients" and were illustrated in Table 7. A similar table must be constructed for the forward linkages by calculating a set of coefficients:

$$a^*_{ij} = X_{ij}/X_{\cdot i}$$

where each element of the Input-Output Table is divided by the row total. Using the data provided earlier, Table 9 shows these forward or supply linked coefficients. This table shows the distribution of output for each of the processing sectors, the distribution of sales. Sales provided by the processing sectors provide the locally supplied inputs to the purchasing sectors. Excluding the total and the coefficients found in the final demand column, the elements of the Table of Forward-Linked Coefficients form a matrix (A^*) similar to the matrix described earlier (A). As was done before, the elements of the forward-linked multipliers are constructed:

$$(I - A^*)^{-1}$$

These elements are shown in Table 10. Again, as before, the horizontal sum of all coefficients is interpreted as the supply multiplier for a processing sector.

Table 9. Sample Table of Forward-Linked Coefficients

Processing Sector	Purchasing Sector				Final Demand	Total
	A	B	C	D		
A	.07	.09	.02	.12	.70	1.00
B	.02	.07	.35	.11	.45	1.00
C	.32	.06	.03	.23	.36	1.00
D	.00	.31	.08	.19	.42	1.00

Table 10. Sample Table of Forward-Linked Multipliers

Processing Sector	Purchasing Sector				Total
	A	B	C	D	
A	1.12	.24	.11	.22	1.69
B	.02	1.53	.48	.32	2.35
C	.41	.32	1.18	.42	2.32
D	.12	.61	.11	1.40	2.24

An alternative approach does not involve manipulation of any tables in the backward-linked approach to input-output (CSC, ca 1969; BEA, 1977). The first and fundamental step is to determine the relationship between a change in output of the supply industry (processing industry) and the associated change in final demand in that industry. This relationship can be expressed:

$$\Delta FD_j = \Delta X_i (1/A_{ij})$$

where ΔFD_j is the change in final demand in industry; associated with a change in output of industry i , ΔX_i is the output change of industry i , and A_{ij} is as before. Given this level of new export demand, the change in total gross output can be calculated as before:

$$\Delta TGO = \Delta FD_j (FDM_j)$$

Please note: if the change in supply (ΔX_i) is expected to result in changes in final demand for several sectors, this process should be extended to these sectors.

Indirect Versus Induced Effects: In the beginning of this discussion of input-output analysis, a distinction was made between "open" and "closed" models. The distinction involved treatment of the final demand sector. If this sector were present, the model was termed "open". In reality, the real issue is the degree of openness. The basic problem involved identification of sectors that are part of the producing economy (endogenous sectors) as opposed to those outside the economy (export or exogenous sectors). These decisions will affect the entire analysis and specifically the multipliers generated.

The nature of any multipliers developed in an input-output analysis depends on how the analyst constructs the flow of transactions between sectors - the linkages. Treatment of the household sector is pivotal, since it can be handled in different ways. One way is to treat households only as primary suppliers of inputs and as demanders of final products - not part of the producing economy. In this case, increases in economic activity are due solely to successive rounds of interindustry transactions called "indirect" or "linked effects" (CSC, ca 1969). Multipliers calculated under this convention are termed Type I. Alternatively, if it seems more reasonable that increased economic activity leading to increased household income will result in increased household expenditures within the region, households should then be treated as part of the producing economy. Increases in economic activity, in this case, are not only due to interindustry transactions of private business (indirect effects), but also to households responding income - called "induced effects". Multipliers calculated on the basis of indirect and induced effects are termed Type II. Since Type II additionally includes induced effects, these multipliers must be larger than Type I counterparts. When Type II multipliers are developed, the household sector is simply included in all matrix calculations which would be expanded to the extent of one row and one column.

Uses of Input-Output Analyses: Most input-output studies available for use in forestry emphasize large geographical areas, such as a state, province or region of a country. This geographical orientation may be inappropriately large. The analyst can either use existing studies, ignore input-output as a tool, or build a more appropriate model. Several input-output studies in forestry have been specifically designed for a county or group of counties such as in New Mexico (Drake et al, 1973), Idaho (Herbst, 1972), Minnesota (Hughes, 1970), California (Fowler, 1974). But because input-output is a very expensive form of study, many analysts rely on existing data to develop models. All other things being equal, the larger the geographical scope, the more expensive the study, and hence the greater tendency to use existing data. To illustrate, a multi-county input-output study in Idaho (Herbst, 1972) relied on an overall Idaho study (Rafsnider and Kunin, 1971a) which in turn was based on an earlier national study (USDC, 1969). On the other hand, a Minnesota study (Hughes, 1970) and a multi-county area study in Indiana (Reimer, 1969) involved collection of primary data. In local economic impact analysis the most useful type of input-output study would probably encompass a one- to three-county area for which data were specifically collected.

While use of existing data helps to avoid the expense of collecting primary data, another problem surfaces: the technical coefficients found in an input-output study pertaining to a large geographical area may be inappropriate for internal areas. The assumptions necessary to apply broad studies to small areas may be prohibitive. Generally, the assumption that the same pattern of linkages that exists for the larger area applies to the smaller one is dubious. Coefficients from the large area must, therefore, be transformed or otherwise made applicable to the smaller area. The problems and prospects of making needed transformations have been discussed elsewhere (Youmans and Stoevener, ca 1973; Rafsnider and Kunin, 1971a).

Input-output studies in forestry have been developed for two distinct purposes: a) to primarily develop a set of multipliers and b) to analyze the net consequences of a specified real change in an economy. These need not be mutually exclusive. The problem faced by most analysts is that existing studies may not be perfectly applicable to the situation being analyzed. What can be done? The data in an Input-Output Table certainly cannot be used because they are applicable only to a different specific situation. But the linkages between industry sectors shown in the other tables may be useful, to the extent that economies are similar. If two economies are similar, their coefficients would also be similar. Multipliers may also be similar. For example, two studies found an income multiplier of about 1.7 for the sawmill and planning mill sector of Idaho (Rafsnider and Kunin, 1971b) and the South (Kaiser and Dutrow, 1971). The difficulty faced by analysts attempting to use previous studies is that detail and computational capabilities available to the original authors may not be available to the analysts. Published multipliers may be the only usable information.

Discussion of input-output analysis will be concluded with a final remark and an example (Table 11) of applying backward linkages to a forestry project. The comment first. Most input-output analyses begin with an initial change in supply or final demand. They end with a measurement of aggregate change either in terms of total gross output, wages or earnings, or employment. The analysis that stops at this point is ignoring a major advantage of input-output analysis. For not only should the analyst be concerned with primary and aggregate impacts, but also with the distribution of these impacts as well. The analysis should disaggregate the aggregate impacts back to the industry sectors from which they came. If employment is to increase by 100, identify the industry sectors which will comprise this change - 50 in the forest products industry, 30 in the construction industry, and so forth. Data available in various tables will allow this to be done. And finally, even if the analyst does not have the computing capability to determine the direct coefficient or to invert a matrix, the original Input-Output Table at least describes a pattern of industry linkage. At minimum, this information can be used to identify and describe sectors likely to be affected by a forestry project.

Table 11. Example: Calculation of aggregate impacts with backward linked input-output multipliers

Backward Linkage Effects

\$ 10,000 change in value of output of the Forest Products Sector (11) exported from the region

ΔTGO = change in total gross output of all industries due to change in demand for exported output of industry j

ΔTE = change in total earnings in the region due to change in demand for exported output of industry j

ΔDE_j = change in demand for exported output of industry j

M_j = regional multiplier for industry j

e_j = factor for converting a change in gross output to a change in earnings

a_{hj} = household coefficient for industry j , representing sales of households (labour) to industry j

$E.$ = national earnings/gross output ratio = .3008

Given: $\Delta DE_j = 10,000$ From Figure 2: $M_j = 1.556$

$E. = .3008$ $a_{hj} = .0890$

Change in total gross output: $\Delta TGO = \Delta DE_j (M_j)$

$$= 10,000(1.556)$$

$$= 15,560$$

Change in earnings: Step 1 - $e_j = (1/M_j) (a_{hj}) + (1-1/M_j) (E.)$

$$= (1/1.556)(.0890) + (1-1/1.556)(.3008)$$

$$= .0572 + .1075$$

$$= .1647$$

Step 2 - $\Delta TE = \Delta TGO(e_j)$

$$= 15,560(.1647)$$

$$= 2562.48$$

Change in total employment:

f = regional employment/earnings ratio

ΔTM = change in total employment in the region due to change in demand for the exported output of industry j

Step 1 - $f = \frac{\text{total employment in the region}}{\text{total earnings in the region}}$

$$= 520,800/3,744,900,000$$

$$= .00014$$

Step 2 - $\Delta TM = \Delta TE(f)$

$$= 2562.48(.00014)$$

$$= .36$$

5. IMPACTS ON INDIVIDUAL WELFARE

The second major component of the distributional consequence model being developed involves assessments of likely adjustments in the economic welfare of individuals living in the local area. Basically, these assessments involve measurements on the "quality of economic life" - as opposed to the "quantity of economic life". The concept of economic welfare has and continues to successfully evade economic theoreticians. The following, therefore, is not to be interpreted as a comprehensive and cohesive treatment of individual welfare. Rather, the impact indicators recommended were selected on the basis of their presumed relevancy and feasibility to be measured. Much of the information needed to measure these indicators comes from the earlier discussion of aggregate changes in economic activity. Three indicators are recommended. Adjustments in unemployment rates will be considered first.

5.1 Unemployment Rates

Unemployment rate refers to the percentage of the total labour force that is unemployed, as determined by some standard or definition. A distinction is normally made between unemployed individuals actively seeking employment and those not actively seeking employment. Unemployment rates usually refer only to those actively seeking employment. Note also, the magnitude of this rate is a function of the definition of the labour force. This definition often refers to the concept of "covered workers" discussed earlier and some age limitation - for example, individuals older than sixteen years of age. This indicator should be viewed as an aggregate measure of individual welfare, reflecting the ability of people to find and secure gainful employment.

The analyst should interpret changes in unemployment rates in a national or regional, as well as local, context. Maintaining proper perspective is important. Consider an expected unemployment rate increase for a local area. A depressed national or regional economy may stimulate further increases in this rate while national or regional expansion may serve to mitigate or offset any negative effects. What about the trend toward increasing the number of females and multiple job holders in the labour force? The analyst concerned with "heads of household" might temper unemployment rate assessments. The point is that both the composition and context of unemployment are important and need to be defined in each case.

It is difficult to assess, *a priori*, whether a forestry project will give rise to a net increase or decrease in unemployment in a locality. For example, it is not altogether clear that an increase in timber harvest will result in a net decrease in unemployment. One aspect of this involves the issue of industrial capacity. Briefly, if the forest products industry has excess capacity - under-utilization of existing labour and capital resources - , more timber to be processed may not give rise to any change in employment and hence have no effect on unemployment rates. Another aspect of this issue involves the notion that industries may be thought of as being complementary or substitute, relative to labour market activity. A positive (or negative) impact on the forest-based industry would have a parallel impact on a complementary industry. The impact would be reverse in the case of substitute industries; a loss for one is a gain for the other. Examples of substitute industries might include sawmills versus plywood mills while complementary industries might be sawmills and transportation. The net effect on unemployment rates is a function of the mix of these industries in a local area. This point is

illustrated in the listing below (Rafsnider and Kunin, 1971b). Changes in employment levels result from changes in timber harvest. The exact amount of change and the specific industrial sectors indicated are not important. What is important is that while a decrease in timber harvest activity will have a negative impact on the Forestry and Fishery Products sector, tending to increase unemployment rates, it has a positive effect on the other sectors. Similarly, while the net impact of the harvest increase was +5.95 person-years, it could have been negative, depending on linkages between industries.

<u>Sector</u>	<u>Forestry Decrease</u>	<u>Forestry Increase</u>
Forest and Fishery Products	-1.78961	7.15122
Agricultural, Forestry and Fishery Services	.08546	- .34042
Forest, Greenhouse and Nursery Products	.01673	- .06472
Meat, Animal and Misc. Livestock Products	.20049	- .79595
Total	<hr/> -1.48690	<hr/> 5.95013

Any assessment of the change in unemployment rate must begin with measurement of employment impacts. Assuming the analyst has information on the labour force and unemployment levels in the local area, the net change in the area's employment could then be used to estimate the new unemployment rate. This procedure, of course, requires the assumption that new employment opportunities would be filled by the existing unemployed labour force. There are problems with this assumption, including the possibility that "full employment" already exists.

The opposite situation, that of an employment decrease, poses a different problem. What assumption should be made relative to where displaced workers will eventually go? Consider the case where discouraging unemployment rates were already projected for an area - Douglas County, Oregon, in this example (Schuster, 1976b). How would a changed level of employment affect these rates? The answer depends on what happens to the displaced workers. For example, assume that a forestry project would decrease employment by 71 employees in 1970 and 32 in 1976. The listing below shows that if the displaced workers cannot find employment in Douglas County, two choices exist: remain unemployed or leave the county. As shown, in either situation, little change in unemployment rate could be expected. The modest consequences in 1976 result from the high unemployment rate already projected for Douglas County and from overall technological advance - fewer timber industry workers per unit of timber processed.

<u>Characteristic</u>	1970		1976	
	<u>Stay</u>	<u>Leave</u>	<u>Stay</u>	<u>Leave</u>
Labour force (without)	28 860	28 860	29 670	29 670
Unemployed	2 290	2 290	5 230	5 230
... Rate	7.9%	7.9%	17.6%	17.6%
Unemployed change	71	71	32	32
Labour force (with)	28 860	28 789	29 670	29 638
Unemployed	2 361	2 290	5 262	5 230
... Rate	8.2%	7.9%	17.1%	17.6%
Change in rate	3.8%	0.0%	0.6%	0.0%

Analysis of the effects of forestry projects on unemployment rates usually stops at this point - with calculations of an expected unemployment rate. But should it? Again, the loss of employment opportunity is particularly troublesome. Put in its simplest form, the question is: What happens to forest industry workers when they are permanently displaced from a current job through production cutbacks or plant/operation closure? Schuster (1976a) has argued that what happens to displaced workers can be conceptually linked to adaptability and mobility. Adaptability is the key. The ability of displaced workers to find employment is but one aspect or measure of their overall adaption to a new environment - this can be termed employment adaptability. What determines the employment adaptability of an individual worker? Probably three things: the worker's relevancy, flexibility and circumstance.

Relevancy refers to the technical or machine aspects of the worker in terms of job performance. The worker is a part in a machine, a factor in a production process. Focus is on the quality and interchangeability of this part, its age and efficiency.

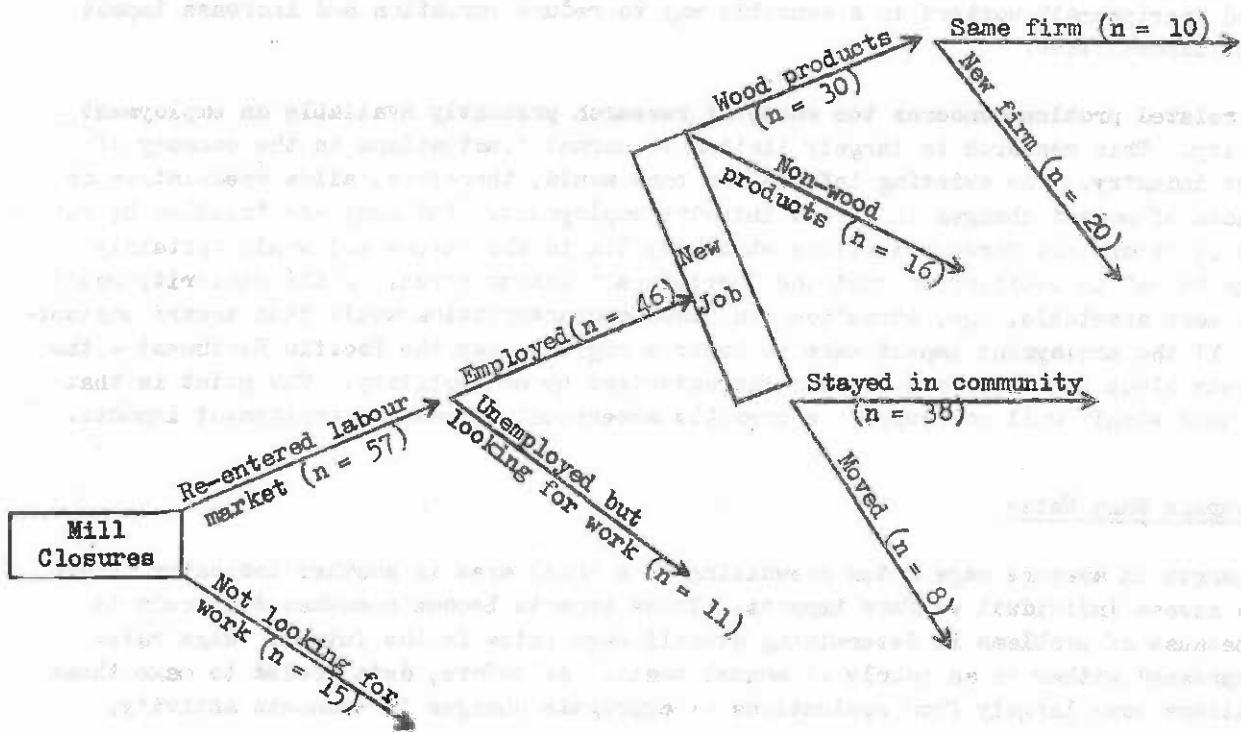
Flexibility refers to the sociopsychological makeup of the worker that gives rise to an inherent propensity toward employment mobility. Mobility can take the form of both geographical and occupational or industrial mobility.

Circumstance refers to the overall socioeconomic environment within which the worker must function. The worker's economic independence, family status and expectations regarding the future are important aspects of the decision context.

Clearly, this model is incomplete and lacks specificity. For example, it is obvious that an interaction term is needed - as circumstance changes, propensity toward mobility may follow. But it is fruitful to separate these elements; conceptually each can have an independent effect on adaptability.

Very little empirical evidence can be presented to indicate the adaptability of forest industry workers to job displacement - a substantial empirical literature does not exist. Much work needs to be done. However, one of the best single sources of data on this point is the work being done by Stevens (1976) on displaced workers. The studied workers that were displaced by mill closure were generally either reemployed or not looking for work. Figure 6 shows the pattern of employment adaptation for workers associated with three mill closures. At the time of data collection, about 81 percent of those looking for work were rehired; 89 percent stayed in the community; and 35 percent of the reemployed left the forest industry. These adjustments in employment took time. Workers at several mills studied average 10-15 weeks of unemployment. At one mill almost half of the workers were immediately reemployed by other mills. Please note, these conclusions are not being presented as universally applicable results. Rather, they are intended to illustrate that initial calculations on unemployment rates need to be further analyzed. Otherwise, the analyst may leave the decision-maker with a false impression of unemployment impacts.

Figure 6. Adaption to closures by sample of 72 workers, Oregon.



Source: Stevens, 1976.

A concluding comment on unemployment rates seems appropriate. Unemployment rate assessments are based on data aggregates. But are the data too aggregated? Steven's work would suggest so, through the concept of the dual labour force. In the process of conducting a state-wide survey of Oregon forest industry workers, Stevens (1976) identified a labour force almost two-thirds larger than that estimated in census data (about 68 000). Termed a "dual labour force", it consisted of about 65 000 "core" workers and 45 000 "peripheral" workers. Their characteristics are totally different. Core workers constituted the permanent, non-mobile labour force - older, less educated, averaging over thirteen years employment with the forest industry. By contrast, the peripheral labour force is highly mobile and workers averaged only slightly more than two years of employment. Gallaway (1967) makes substantially the same point regarding hired agricultural workers; after the forty-year age class, out-migration stops and, in fact, a low level of in-migration was found.

The upshot of the dual labour force is that:

- a) The burden of labour force reductions will be borne by the peripheral labour force which will likely face reduced job prospects because of the history of changing jobs.
- b) The core labour force is relatively secure and the seniority of this group will enhance reemployment prospects in the forest industry.

One reasonable conclusion is that stratification of the forest industry labour force into "core" and "peripheral" workers is a sensible way to reduce variation and increase impact assessment capabilities.

A related problem concerns the scope of research presently available on employment adaptability. This research is largely limited to normal fluctuations in the economy of the forest industry. The existing information base would, therefore, allow speculation on consequences of modest changes in forest industry employment. But many are troubled by the prospects of major work force reductions which may lie in the future and would certainly affect the "core" in addition to just the "peripheral" labour force. While seniority would make them more adaptable, age, education and other characteristics would tend toward unadaptability. If the employment impact were to cover a region - say the Pacific Northwest - the picture gets bleak for these are workers characterized by non-mobility. The point is that the data base simply will not support a credible assessment of massive employment impacts.

5.2 Average Wage Rates

Changes in average wage rates prevailing in a local area is another indicator recommended to assess individual welfare impacts. These impacts become somewhat difficult to measure because of problems in determining overall wage rates in the future. Wage rates can be expressed either on an hourly or annual basis. As before, data needed to make these determinations come largely from evaluations of aggregate changes in economic activity.

Determination of wage change has already been discussed. But remember, any particular change in aggregate wages need not be associated with an analogous change in wage rates. The average wage rate that will prevail in a local area after a project is implemented will depend on: a) the way employment gets restructured in industries and b) the prevailing wage rates in those industries. Assume, for example, that a management activity change elicits no net change in employment, but internal adjustments occur. If these adjustments are in favour of high-paying industries, the area's average wage rate will likely go up. If the adjustments are in the opposite direction, the converse will be true. The analyst should make an effort to identify these shifts. If a quantitative assessment of shifts is impossible, a qualitative judgement of probable consequences should be made.

The differential effect on wage rates resulting from a shift of employment from one industry to another was recently illuminated by Polzin and Schweitzer (1975) - although for quite a different purpose. They were evaluating the economic importance of the tourism industry versus the wood products industry in Montana. Their data indicated that while annual wages and salaries in the wood products industry averaged about \$8 300 in 1971, wages and salaries in the tourism industry generally averaged less than half that amount. Given that relationship, any employment shift from the high-paying industry to the lower-paying industry will result in a lowering of average wage rates.

Ability of the analyst to accurately measure a change in average wage rate is almost exclusively a function of the data base used. Two situations may exist. On the one hand, the analyst may base assessments on aggregate change and aggregate data. Assume that total wages in an area were \$101 160 000 without initiation of a forestry project, and \$100 649 122 with the forestry project. The listing below shows that if the "without" average wage rate were used to determine the "with" employment level, no change in average wage rate can be identified.

<u>Characteristic</u>	<u>Without</u>	<u>With</u>
Payroll	\$101 160 000	\$100 649 122
Employment	16 045	15 963
Average Wage Rate	\$6 305	\$6 305

The reason for this is that only aggregate changes were involved. That is, workers left the employed labour force at "average" wage rates. Unless the change in employment is associated with differentials in wage rates, no change in average wage rate will be detected. This result will occur when either economic base or input-output analysis uses proportional or linear relationships to assess wage and employment impacts.

However, changes in wage rates can be detected if the analyst can segregate wage or employment changes into industrial categories. Consider the data in the listing below. The "with" column of wages was calculated on the basis of the "without" wage rates together with the "with" distribution of employment. Obviously, any employment shift toward the higher paying industries is shown, resulting in a four percent average wage rate increase. Does the analyst need to use the "without" wage rates as a basis to determine the "with"? No. The "with" rates may be projected on the basis of time series data. Indeed, to use the "without" wage rates requires the major assumption of stable wage relationships.

<u>Industry</u>	<u>Without</u>	<u>With</u>		
	<u>Wage Rate</u>	<u>Employment</u>	<u>Wages</u>	<u>Wage Rate</u>
Forest Industry	\$ 8 000	40 000	\$ 320	\$ 8 000
Other #1	6 000	35 000	210	6 000
Other #2	10 000	25 000	250	10 000
Composite	\$ 7 500	100 000	\$ 700	\$ 7 800

The analyst should make every effort to ensure that average wage rate determinations are as realistic as possible. All other things equal, changes in these rates will affect the amount of purchasing power available to individuals in the area. The discussion above was couched in terms of average annual wages. As before, earnings could be used instead of wages. Similarly, other measures could be used. For example, the analyst may rather convert income levels to a per capita basis or income per household. Final decisions should consider the information needs of the decision-maker.

5.3 Income Re-distribution

Change in income distribution is the final indicator of individual welfare that will be considered. There are several ways this issue could be addressed (Waggener, 1976a). One is to describe the types of workers and individuals in terms of social characteristics and industrial affiliations. There tend to be "winners" and "losers" as a result of a new project; income is being re-distributed in favour of some and away from others. It may be valuable for a decision-maker to know if an already disadvantaged segment of the local area will be aided or further disadvantaged. These types of evaluations may have to be qualitative and subjective. Research is currently underway to improve knowledge in these areas (Stevens, 1975; YoungDay, 1975).

Input-output analyses can also be used to identify distributional effects in a manner less analytical than discussed earlier. Sectors of the economy most likely to be involved in a change in aggregate economic activity can be identified. Any of the tables resulting from an input-output study could be used, depending on the analyst's purpose. Consider the case of the Input-Output Table; it shows dollar flows from producing to consuming sectors, and vice versa. The listing below shows the pattern of sales and expenditures for sawmills in Sullivan County, Pennsylvania (Gamble, 1967). Changes in the sawmill industry would have initial or first-round repercussions for those sectors shown, probably related to the magnitude of the percentages. If knowledge of subsequent repercussions were desired, the table of inverse coefficients would be more useful. Using input-output analysis in this manner is particularly helpful when the analyst has tables available but lacks the facilities (e.g. computer capability) to evaluate the specific project change in question.

<u>Sector</u>	<u>Purchases</u>	<u>Sales</u>
Agriculture	0.8	0.4
Sawmills	4.7	4.7
Construction	0.0	0.7
Gas stations	1.6	0.0
Non-profit personal services	3.3	0.0
State A	7.6	0.0
Labour	21.7	0.0
Proprietary income	24.5	0.0
Other internal	3.3	0.1
External to county	32.5	94.0
	100.0	100.0

On the other hand, an operational input-output analysis can be used to actually measure certain types of distributional effects. The Consulting Services Corporation (ca 1969) conducted several evaluations for the Public Land Law Review Commission. One case study involved predicting the impact on employment that would result from a 50 percent increase in carrying capacity of range lands on the upper main stem of the Colorado River by 1980:

	<u>Employment Change</u>	<u>% Output Change</u>
Range livestock	1 692	32.01
Dairy	-51	-32.69
Food & field crops	-121	-30.75
Other retail	97	0.61
Rentals & finance	32	1.33
Household	116	-
Other	151	-
Total	1 916	1.25

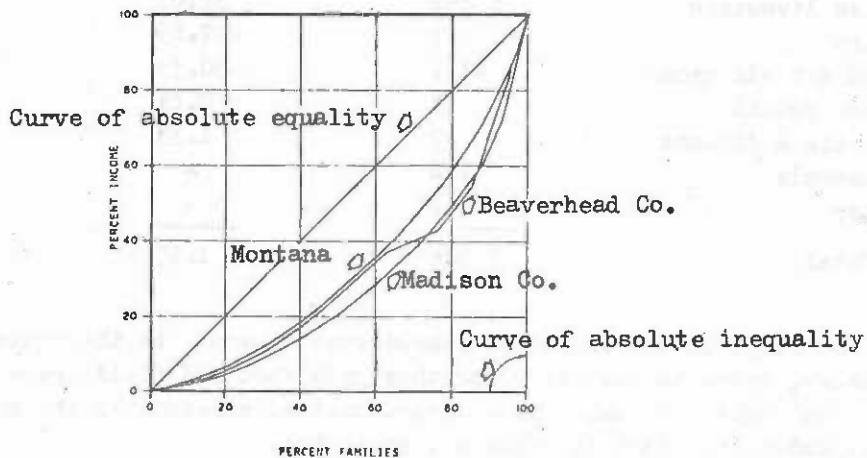
While persons in the range livestock and household sectors would be the prime beneficiaries of this policy change, those in the dairy together with food and field crops sectors would be disadvantaged. But again, to make these distributional assessments the analyst must have computational capability that is often not available.

Input-output analysis can be used in a slightly different way. Darr and Fight (1973) computed an index of dependency for each sector relative to all forest-oriented sectors. This index was based on both direct and indirect effects. The listing below shows the five most significant non-government sectors expected to be made relatively worse-off and relatively better-off. While no sector is expected to be made absolutely better-off, sectors with the smallest negative impact are, in a relative sense, better-off. On balance, income will be redistributed in favour of visitors, horticulture and livestock interests and away from the timber-using industries, households, and automotive sales and services interests.

<u>Sectors</u>	
<u>Relatively worse-off</u>	Household Automotive sales and services Financial services Retail and wholesale trade Construction
<u>Relatively better-off</u>	Visitors Horticulture Livestock Other manufacturing Commercial fishing

Another less personal indicator of income distribution involves a measure of income inequality among classes. Conventionally, this means applying the concept of a Lorenz Curve to the problem of quantifying income equality. Figure 7 illustrates these curves for selected Montana counties and for the state as a whole in 1970. Data are normally available in the Census of Population to define a curve for a local area at some point in time. The analyst must estimate a new curve to determine the effect of a change in management activity on income equality. This may, again, be a subjective assessment. No systematic procedure is known that would facilitate this effort.

Figure 7 - Graph of cumulative income distribution



Source: U.S. Forest Service, 1974

However, it may be useful to indicate the general direction of such an analysis. The data below (USDC, 1973) show the change in income distribution resulting from 80 workers being displaced:

Income Class	Before Change			After Change		
	Families	%	Σ	Families	%	Σ
<\$1 000	523	2.8	2.8	603	3.2	
1-1 999	786	4.1	6.9			
2-2 999	916	4.8	11.7			
3-3 999	902	4.7	16.4			
4-4 999	915	4.8	21.2			
5-5 999	1 191	6.3	27.5			
6-6 999	1 400	7.4	34.9	1 364	7.2	
7-7 999	1 788	9.4	44.3	1 744	9.2	
8-8 999	1 623	8.5	52.8			
9-9 999	1 499	7.9	60.7			
10-11 999	2 496	13.1	73.8			
12-14 999	2 359	12.4	86.2			
15-24 999	2 146	11.3	97.5			
25-49 999	435	2.3	99.8			
50 000+	38	0.2	100.0			
Total	19 017			19 017		

Forty-four workers were displaced from the timber-using industry where average incomes lie in the \$7 000 to \$7 999 class, while the remaining 36 workers were withdrawn at county average wage levels (USDC, 1971). Only the sectors changed are shown. A major assumption is that each employee represents one family unit. These data could be plotted on a graph such as Figure 7 shown earlier. It is clear that if these data were calculated and plotted, the new curve would show less income equality. While this change is admittedly slight (due to the specifics of this problem), the principle is more general and warrants consideration.

6. IMPACTS ON ECONOMIC EQUILIBRIUM

Introduction of a new forestry project or activity may have an impact on economic equilibrium or stability of the local area. Stability refers to the ability of the area to maintain its economic viability over time. It may seem difficult to separate indicators of equilibrium or stability from economic activity. An example may help clarify the distinction. The Western U. S. is dotted with ghost towns - the remains of once thriving mining communities. One could imagine decisions favouring mining years ago that ranked high on indicators of economic activity - income and employment of the time. But in terms of maintaining area equilibrium, these decisions may, in retrospect, be judged as somewhat lacking. Stability considerations add a long-range time element to impact analysis. Two broad indicators of future community stability seem worthy of note.

6.1 Economic Diversity

A fundamental axiom in the field of ecology is that the more diverse the ecosystem, the more stable it is. The analogy can be made to community equilibrium/stability and economic diversity. Ecosystem diversity insulates and ensures permanence of the system against natural catastrophe. So it is with economic systems. After the gold and silver were extracted, many communities were left without an economic base. The collapse of mining signalled the demise of the community, and ghost towns resulted.

The existence of "ghost towns" dramatizes the fact that economic processes are seriously jeopardized in an unstable environment. The most useful measure of economic diversity seems to be the distribution of economic activity among sectors. Distribution of employment would serve as an indicator. A management alternative would be judged to promote stability if it enhanced diversity as measured by a more equal distribution of employment among sectors. By this measure, to make a timber-oriented community more timber-dependent would not be desirable. Clearly, if carried to an extreme, this indicator may be incompatible with economic base theory. Diversity would tend to discourage further specialization; development of export or basic industries would not be emphasized. Therefore, area growth would be diminished.

Consider an example of one possible approach to a diversity calculation. Upon reflection, it will be discovered that diversity has a statistical counterpart - variance. A system of numbers that are all very similar will have relative low variance. Since similarity (a more equal distribution) is suggestive of more diversity, it follows that relatively lower variance levels will be associated with relatively more diversity, and hence stability. The analyst may conclude that the standard expression for statistical variance might be a useful expression of a diversity index.

$$\sigma^2 = \frac{\sum (x_j - \bar{x})^2}{N} = \text{Diversity Index}$$

Given the data in the listing below, the diversity index for the status quo is calculated to be about 139, Alternative 1 to be 1 667 and Alternative 2 as 50. On the basis of these calculations, Alternative 2 would be found to be the most diversified and hence most stable. Clearly, the above expression for variance emphasized deviation from a mean, more than would some other measures. The analyst should adopt some measure of diversity. It need not correspond to the variance expression shown above.

<u>Sector</u>	<u>Expected Employment</u>		
	<u>Status Quo</u>	<u>Alt. 1</u>	<u>Alt. 2</u>
A	25	25	35
B	25	25	35
C	50	75	50
	<u>100</u>	<u>125</u>	<u>120</u>

Another approach to economic diversity deals with industrial location. How will decisions today affect long-range expansion or contraction of industrial activity? The environment created for industrial location in the local area will certainly affect community equilibrium and stability.

The body of literature existing in the area of industrial location is wide-ranging (see Hoover, 1948; Mueller and Morgan, 1962). While much more restrictive, the literature concerning forest-based industries is still impressive. Most of these studies address the question of which factors (taxes, land prices, etc.) influence the decision of a firm to locate in a particular area (e.g. Hagenstein, 1964). Availability of wood, raw material, labour and transportation is often most important in timber industry location decisions. McMillan (1965) provides a reasonable synopsis:

If an industry is resource oriented, it must place prime importance on raw materials. If the manufactured product embodies high labour costs or highly skilled labour, labour market conditions occupy a position of prime importance. No plant can justify its existence without a place to sell its output. Therefore, markets must rank high. But these are not determinants of a particular location. Instead, they are prerequisites to operation. Transportation may also fall into this category of prerequisites. (emphasis added)

While communities can do little about raw materials, markets, population and certain forms of transportation, public land managing agencies can certainly affect one - raw materials.

There are two important implications of forest management decisions on industrial location. First, these decisions need not affect location of all resource-oriented activities in the same way. Given a resource base and some capacity to produce outputs, a decision against one resource output may at the same time be a decision in favour of another - to increase timber availability may discourage industrial location of recreation industries. The consequence is unavoidable. As a corollary, since many factors other than timber raw material affect industrial location, timber management decisions may not be sufficient to create or maintain a desirable environment for industrial location. The second implication relates to the concept of "comparative advantage". Assume a situation involving only one resource-oriented industry, a timber-based industry. Assume further that a comparative advantage exists for this industry due to availability of wood raw materials. A decision to restrict this availability could have negative location consequences by eliminating the major (and possibly the only) reason firms locate in that particular area. The point is that major forest management decisions cannot avoid long-range industrial location implications.

6.2 Community Adjustments

It is important for the decision-maker to realize that a major decision on forest management projects may inextricably alter a community. The decision may lead to a fundamental change in the economic fabric of a local area. While communities may always be in a constant state of change, radical acceleration or departure from trends may have a strong impact on local equilibrium. The analyst should attempt to assess the implications of a forestry project in terms of adjustments in community lifestyle, social disorganization and local values.

Lifestyles - Lifestyle is the "way of living" chosen by individuals, groups and communities. More specifically, lifestyle is a composite of various elements resulting from the interaction of human beings with their physical and social environments. Included in these elements are use of time and attitude toward, and methods of interacting with other people and with the physical environment. Lifestyle is defined by the way these elements combine. Some consider lifestyle analysis to be synonymous with social impact assessments (Holden, 1975).

Lifestyles are also a reflection of the way people meet their physiological and psychological needs. People engage in activities they value; those who enjoy outdoor activity may be concerned about the effects of resource allocation decisions on national forest recreation. Those who make their living from mining, lumbering or grazing are likely to oppose decisions that remove land from these uses. Conflict of lifestyle, and hence land use, is inevitable. The potential conflict resulting from resource allocation decisions is largely one of local versus regional and national interests, as well as group versus group. It is important to understand that the needs and desires of local people are usually different from those of outsiders. While outsiders venture to the local area to meet certain needs, locals meet almost all needs in this area. As outsiders demand increase, lifestyles of the local population can become threatened.

In an overview of social impact assessment, Gale (1977) describes lifestyle measurement as follows:

The term 'ways of life' or 'lifestyle' represents a way of characterizing a cluster of specific social variables. Use of this social impact category is a good way to avoid a variable-by-variable description of different groups within a community. Summaries such as 'the lifestyle of those expected to move into the area under the action alternative ...' reflect a gathering together of a number of variables.

There is no 'standard set' of five or ten variables used consistently to describe a way of life or lifestyle. In identifying lifestyles, the focus is on those three or four variables or components which, in a particular situation, best characterize the relatively distinct way in which a certain group of people go about their daily activities.

'Distinct' is a key word in understanding lifestyles and in assessing impacts on them. For identifiable lifestyles to exist, it is not necessary for two groups to differ in almost every aspect of their daily lives. More typically, different lifestyles emerge as an increasing number of characteristics differ, although some common elements will remain.

Lifestyle impact analysis is still in its infancy. Wolf (ca 1974) terms the current state of the art as "explosive" and predicts "orders-of-magnitude" improvement in the near future. Present efforts seem to focus on descriptive analysis - often termed ethnographic studies (ISR, 1974). Predictive analyses are not commonplace and the analyst of adjustments in community lifestyle must often rely on informed judgements. Fortunately, significant recent work by Gale (1975) and Freeman (ca 1976) are adding to the set of tools and concepts needed to make these assessments.

Social Disorganization - The disorganization of a local area's social fabric together with lifestyle adjustments are primarily concerns of sociologists. Nevertheless, both strongly influence community longevity. It is difficult to imagine economic stability in the absence of social stability. Social disorganization refers to stress, to the point of severance, placed on the internal linkages that bind institutions together.

Social scientists group a wide variety of elements under the heading of social disorganization. The theme common to these elements is disruption of normal social processes. For example, consider the possible increase in the unemployment rate discussed earlier. Social disruptions and turmoil associated with massive unemployment are obvious. Further, a type of multiplier effect might exist, entailing additional stresses on community support facilities, family stability and overall morale. Major forest management decisions can lead to social disruption by changing the political power structure and reordering the economic structure of the local area.

Local Values - One of the most striking features of local economic impact studies is the cavalier way in which some analysts designate "good" impacts and "bad" impacts. More employment is "better" than less. Increases in the level of economic activity are "good." These "values" are implied in many analyses. The analyst should realize that impact indicators must be viewed as neutral. Implying goodness or badness is a value judgement. Analysts, probably inadvertently, have fallen into the trap of making value judgements about indicators.

Since the focus of most social impact analyses is the local area, it seems reasonable that the local people should make value judgements. Communities differ. The values shared by people in one area may not be shared by those in another. A "sense of community" may be at issue. The way people in a local area see themselves and their community should be considered. Take a small, rural, conservative, close-knit community in the Southwestern U.S. This community might react very differently to the prospect of 50 new jobs which might be filled by "outsiders" than would a larger metropolitan area. Simply stated, "goodness" or "badness" of indicator measurements should be evaluated, not assumed.

7. IMPACTS ON LOCAL GOVERNMENT

The final area of distributional consequence considered involves the relationship between the forestry project and governmental entities located in the local area. Many of the distributional consequences already discussed will eventually affect the local government. Those considered now are of more direct consequence. Of the many ways a change in forest management activities could affect these governments, fiscal impacts - both revenues and expenditures - are of prime importance. Since there is no uniformity as to either the nature of these fiscal impacts nor the analysis that would be appropriate, the following discussion will provide an overview of the types of issues with which the analyst must deal. Two general indicator areas will be considered.

7.1 Intergovernmental Payments

The relationship between different levels of government (federal, regional, local) will vary not only as a function of the nation in question, but also as a function of specific governmental units and agencies within a social economy. The principle of intergovernmental payments (transfers) has been a long established practice. Some of these payments are the result of specific policy actions designed to accomplish some social purpose. Some just happen. They are the natural result of government exercise of its proprietary power. The analyst should make a careful assessment of these consequences. This will necessarily involve a detailed analysis of the specific circumstance being evaluated. Three general types of intergovernmental payments may be found.

Revenue Sharing Payments - While the concept of one level of government (federal or state) sharing its revenues with a lower level (state or local) has been the subject of recently increased political interest in some countries, it has existed for a long time. For example, the practice of sharing revenues from the sale of public lands in the United States began in 1802 when the U.S. Congress provided that the state of Ohio would receive three percent of the net proceeds of the revenues from the sale of public lands in the state (EBS, 1970). Possibly the first form of revenue sharing in the United States that remains in effect today originated in 1908 with a law requiring that 25 percent of the net receipts generated by national forests be returned to countries in which the forests are

located (U.S. Code, 1908). Other acts have been passed for lands administered by other agencies. The legislative history of these acts reflects that payments to state and local governments were intended as compensation by the federal government, since the lands in question were not available for purpose of local property taxation (PLLRC, 1970). To measure impacts on local government associated with a system of payments-in-lieu-of-taxes, the analyst must first evaluate existing policy - both statutory and administrative. Completing this, the analysis can proceed.

Consider an extremely simplified example of the types of calculations that ought to be made when a forestry project on a U.S. national forest will alter the level of money receipts. The increased receipts may be possibly due to a forestry project that increases receipts from grazing permits because of increased forage available on forest lands. In reality, actual payments to the counties would be determined by the provisions of the 1908 law previously discussed as modified by the 1976 Forest Management Act (U.S. Code, 1976a) and as supplemented by the In-Lieu Tax Act of 1976 (U.S. Code, 1976b). But let us ignore these details and work through the outline of a typical analysis. Assume that annual grazing receipts were to increase from \$400 000 to \$600 000. The other parameters of this example are shown in the following listing:

- Change in receipts - \$200 000
- Payment basis - 25% of receipts
- Change in payments \$50 000
- Distribution of national forest land - County A: 80%
- County B: 20%
- Current county revenues - County A: \$ 5 000 000
- County B: \$10 000 000
- Use of payments - Schools and roads

Given these data, payments to County A would decrease by \$40 000 ($80\% \times \$50\ 000$) and assuming no other change in revenue structure, the new level of revenues to the county would be 99 percent of the old ($(\$4\ 960\ 000 / 5\ 000\ 000) \times 100$). Knowledge of the existing budget for schools and roads could then be used to assess the impact of receipt reduction on these budget items.

In practice, measurement of changes in payments-in-lieu-of-taxes is a very easily measured consequence of a forestry project. At least this is so in the United States. The reason for this is that the data needed to accomplish the analysis are readily available in public records. But the analyst should be aware of two problem areas. The first deals with identifying the change in receipts. The word "net" seems appropriate to highlight the fact that a change in one area of management may be associated with a change in some other area. For example, an increase in grazing receipts may be associated with a decrease in receipts due to timber harvest. The analyst should consider the relationship between these changes. They may or may not be offsetting. The second problem deals with estimating the revenue change associated with the forestry project. One common approach is to use proportions. If timber harvest is to decrease by 50 percent, revenues to the county will decrease accordingly. An alternative procedure is to vary the timber harvest level and then calculate revenue changes on the basis of average stumpage price received over the past several years. Depending on the particular location, either of these methods may be extremely risky. An analysis of U.S. Forest Service revenues in Montana over the 1960-73 period found a correlation coefficient of 0.29 between value and volume of timber cut, while a correlation of 0.97 was found between value and adjusted stumpage price (Schuster, 1976b). This suggests that the prudent analyst should seriously investigate the price element in timber revenue determination.

In-Kind Payments - The second type of intergovernmental payment concerns the contribution made by public agencies that tend to relieve local government of a financial burden. For example, development of a state campground may diminish or eliminate the need for a county to develop a park system. No money is transferred; consequently, the cost savings incurred by the local government are termed payments "in-kind" by the public agency. The key to determining the magnitude of these payments is identifying those activities assumed by the public agency that would normally be accomplished by the local government. There is no uniform agreement as to the list of these activities. The analyst must rely on the advice and consultation of the decision-maker and officials in local government.

Quantification of in-kind payments is not an exact process. The problem is one of data availability. Only a very few studies have been done to determine the levels of in-kind payments; study results are generally applicable to state and multistate areas only. Table 12 shows selected results of some of these studies. If evaluation of in-kind payments is to proceed, the analyst is forced to rely on aggregate levels of payments per acre. Data reflecting a stratification of payments relative to type of management activity are preferred over aggregates. In this way, payments associated with timber management could be applied to programme changes in that area. In-kind payments should be converted to the same base as the management programme. That is, if timber harvest is to be modified, the payments should be expressed in an acceptable unit - dollars per board foot. This procedure implies a strict proportionality that likely does not exist. Yet, the data base does not allow a more refined analysis.

Other Payments - A final area of intergovernmental payments involves secondary payments, payments associated with other governmental programmes. Local governments often receive funds from other government levels on some type of formula or matching basis. If a change in management activity affects the formula, receipts will be altered. For example, a local government may receive aid for education from the state on a student enrolment basis. If management activity leads to unemployment, out-migration of population and withdrawal of children from the local school system, a loss of state school funds is likely. Of course, the reverse could also result from an opposite change in management activity. And finally, when a management activity affects economic activity, it will likely also affect taxes collected by the local government. This change in revenue will change the availability of local matching funds and project funds (e.g. U.S. Bureau of Outdoor Recreation funds for community recreation projects). Measuring this impact indicator would require analysis of a specific local government and its programme involvement.

7.2 Cost to Local Government

A controversy exists in certain areas of the country relative to the financial support relationship between local government and public agencies, Shannon (1975) reports that "many county commissioners believe that county maintenance costs incurred as a direct result of management activities on national forests are far larger and are far more stable than the financial support received directly by county government from the national forests." There are probably many ways in which the mere presence of a major land management agency results in costs to local government. For example, because timber harvest activities require use of heavy logging trucks, county roads must be built and maintained to a higher standard than otherwise necessary. Unfortunately, identification of these cost items is largely at the speculative stage. Since few comprehensive analyses of this topic (EBS, 1970) have been done, generalized assessment of these costs is well beyond the state of the art.

Table 12. Estimated Forest Service Contributions In-Kind per Acre, by Type, FY 1962 and 1952

Region	1962				1952 Total
	Fire Control	Forest Highways	Road, Trail and Other	1962 Total	
(cents)					
Northern	3.5	18.4	4.1	26.0	15.7
Rocky Mountain	1.9	17.5	1.5	20.9	11.9
Southwestern	1.5	15.9	4.0	21.4	21.3
Intermountain	2.5	12.1	3.5	18.1	15.2
California	85.4	24.4	28.4	138.2	54.6
Pacific Northwest	24.3	28.7	8.1	61.1	34.6
Eastern	6.4	17.3	5.9	29.6	19.9
Southern	10.3	16.8	6.8	33.9	23.1
North Central	11.2	14.5	18.6	44.3	23.8
All Regions	16.7	18.7	8.1	43.5	-

Source: U.S. Forest Service, 1965

Another aspect to local government costs should be considered: transaction costs. These are the added costs that must be borne by local government during the period during which adjustments in the local area are made - the transition period. For example, additional pressures may be placed on community service agencies as a result of additional employment. Pressures may be placed on local schools or law enforcement units because of accelerated social disorganization. Because understanding of these transaction costs, especially regarding forest management activity, is totally undeveloped, no known measures exist to evaluate this indicator.

8. CONCLUDING REMARKS

Evaluation of the distributional consequences of forestry projects is an important component in an overall assessment of the desirability of one project relative to another. But it is not the only component and there is no reason to believe it the most important component. Clearly, many other consequences are also important, including economic efficiency consequences and environmental quality consequences. The role and importance of distributional consequences in selecting between alternative forestry projects is a function of the decision-maker's goals and objectives. These not only provide the context for distributional analyses, but they also specify the content of the analysis. Since goals and objectives vary, this paper has adopted a rather neutral position and simply attempted to provide a general overview for analysis. It outlined some considerations, issues, problems and methodologies that often will be encountered in a distributional analysis.

Distributional analyses call for a high degree of ingenuity and adaptability on the part of the analyst. This is partly due to the fact that, at least conceptually, each analysis is different, tailor-made to the specific circumstance being evaluated. While the range of items to be evaluated in a distributional analysis is almost limitless, the impacts evaluated must be limited for very practical reasons of time and money. The analyst must translate the information needs of the decision-maker into operational analyses. Upon completion of the analysis, the results must be translated again into information for decision-making. This is not simply the problem of communication. It is also a problem of interpretation. Initial study results must be interpreted and evaluated with the context of the social and economic structure of the local economy in mind. The response to a given set of distributional consequences will vary from one economy to another. Local areas differ. Their internal linkages, structures, and value systems defy generalization (Dickerman and Butzer, 1975). This sharply reduces the analyst's ability to extrapolate knowledge of the distributional consequences of forestry projects from one area to another. Each analysis must start anew.

The other major factor calling for ingenuity and adaptability from the analyst is that the state of analytical capability is sadly deficient. Although several sophisticated techniques exist, they are only applicable to a relatively small set of consequences. And even for these, the needed data base might not exist. Analytical tools to assess some of the other consequences remain either undeveloped or underdeveloped. The analyst must adapt to these circumstances. Alternative data sources may need to be discovered. Major assumptions may need to be made. The project analyst may find it necessary to call upon the talents of political scientists, sociologists and other social scientists to enhance the quality of the distributional analysis. Ability to recognize deficiencies in data, deficiencies in analytical capabilities, and deficiencies in personal expertise will probably increase with experience. Ability to effectively deal with these deficiencies will depend on the analyst's ingenuity and adaptability.

Over time, the quality of distributional analyses will likely improve. Better data will become available. Analytical techniques will be developed and refined. Analyst expertise will improve. The process takes time. Hopefully, this paper represents a positive part of that process.

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ECONOMIC ANALYSIS OF WATERSHED PROJECTS:

Special Problems and Examples

by

Hans M. Gregersen and K. Brooks

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1. INTRODUCTION

Most forestry projects involve implications in terms of changes in water quality and/or quantity. Thus, economic analyses of most forestry projects should include explicit consideration of watershed related impacts and of potential activities to achieve acceptable watershed protection standards. In some cases the major objectives of a project may be water related and constitute the reason why the project is being considered and proposed. In other cases, water related concerns may merely enter the project analysis in the form of constraints on other project activities. In either case, the economic analyst should have something to say about water related impacts in his analysis.

The above is not to say that the same objectives and/or constraints apply in all situations. Thus, for example, project objectives will vary widely with climatic and landform conditions as well as other factors. Appendix I presents a schematic overview of objectives which tend to dominate in different climatic regions.

Economic analyses of watershed projects are no different in principle or concept than analyses of any other type of project. Thus the general concepts and guidelines presented in FAO's Economic Analysis of Forestry Projects¹ (EAFF) are valid for watershed related projects. However, some analytical issues and empirical problems are particularly important for such projects. Some of these issues and problems relate to economic factors, and they are the main subject of this paper. Others relate primarily to technical factors and their treatment is properly the task of hydrologists, engineers and other technical specialists. Thus, we do not discuss them further here, other than in terms of how the economist can interact with these other specialists in determining what physical input-output information is needed in order to carry out an economic analysis. The basic point is that the physical relationships must be quantified before an economic analysis can be carried out. Thus, the present discussion proceeds under the assumption that such information can be generated. Given the fact that the lack of such information is in practice the major bottleneck encountered in most watershed project appraisals, it may seem that this assumption is made to avoid a major problem. In fact, it is made to emphasise the point that the economist cannot solve the information and data problems associated with watershed projects. What he can do is to (a) suggest a systematic approach to identifying direct and indirect negative and positive impacts associated with a project and (b) point out what information and data are needed for him to be able to value these various impacts. The remainder of this discussion explores these two questions within the overall framework for project analysis set out in EAFF.

The specific points selected for further discussion are the following: ²

1. Consideration of alternative means for achieving goals
2. Determination of project scope and context

¹ FAO Forestry Paper No. 17

² The fact that these are the only six points listed does not mean that they are the only ones of concern to the analyst of a watershed related project. For a more systematic discussion of the entire range of issues encountered, the reader is referred to EAFF.

3. Identifying costs for watershed projects
4. Identifying benefits for watershed projects
5. Treatment of benefits and costs in multiple purpose projects
6. Presenting cost and benefit information in an appropriate form.

In order to provide common empirical reference points during the discussion of each of these, two case study analyses of projects involving watershed considerations are summarized in Section 2. These two examples are then referred to in Section 3, which provides a discussion of the six points listed above. The reader who merely wants an overview of the issues can skip Section 2 (the cases) and go directly to Section 3.

Finally, in order to illustrate the types of empirical information that are required and examples of watershed related project analyses that are already available, a summary of some of the relevant documentation on this subject available from the United States is presented in Section 4. This section also illustrates a number of the general points discussed in Section 3.

2. EXAMPLES

The first of the examples is an economic analysis of alternative logging systems. The objective of the analysis is to find that system that maximizes net revenue subject to constraint on maximum allowable sediment discharge. It is an example of an economic analysis to provide information for an operational decision where water related concerns are entered as a constraint.

The second example illustrates in summary form an economic analysis of a major watershed project designed to reduce the rate of sedimentation in a reservoir, thereby extending the useful life of the reservoir and producing additional downstream benefits. The project also involves several other elements, including wood production in combination with watershed protection, pasture improvement and general improvement of upstream agriculture.

Example No. 1: Watershed Considerations as a Constraint in a Project

The growing worldwide concern for the environment makes this type of problem and this example relevant.

A 20 ha wood lot is to be harvested. The lot occupies land along a river with an average slope of 20-30%. A clearcut will not be allowed by regulatory agencies in order to prevent erosion and decrease resulting sediment flows. For this reason a selective cut will be made. However, it is anticipated that with standard logging techniques about 4 tons of sediment per hectare will enter the river the first year after the harvest. This amount of sediment is considered unacceptable by authorities and they will not issue the harvesting permit unless measures are taken to reduce sediment to no more than 2 tons per hectare. Thus, the forest manager must find an alternative that will reduce sedimentation of the river by at least 2 tons/ha/yr at the lowest cost possible, i.e. he is searching for the least cost alternative for logging the area that will meet the constraint.

Harvestable volume on the woodlot is $300 \text{ m}^3/\text{ha}$ which can be sold for $\$10/\text{m}^3$.

If all 20 ha had been harvested using standard methods, it is estimated that the following costs and returns would have obtained:

Returns: $300 \text{ m}^3/\text{ha} \times \$10/\text{m}^3 \times 20 \text{ ha}$ equals $\$60,000$

Costs: labour: 1 000 man hours $\times \$2.00/\text{hr}$ equals $\$2\ 000$

tractor: 250 hours $\times \$25/\text{hour}$ equals $6\ 250$

loading/transport: 120 hours $\times \$20/\text{hr}$ equals $2\ 400$

total cost: $\$10\ 650$

Net revenue: $\$60\ 000$ minus $\$10\ 650$ equals $\$49\ 350$

However, as mentioned the standard method is not acceptable because of the high sediment discharge associated with it. Two alternatives are proposed that would meet the maximum discharge restriction.

The first feasible alternative consists of leaving a 25 m wide buffer strip (no cutting) along the river. The woodlot has a shoreline of 1 600 m, therefore, cutting would be reduced to a total of 16 ha instead of 20 ha. This means a loss of 4 ha of timber or $300 \text{ m}^3 \times 4 \text{ ha} \times \$10/\text{m}^3$ which equals $\$12,000$ of revenue foregone. This is considered a cost for this alternative. It is assumed that other costs would be reduced by 20 percent since only 16 ha could be harvested. Thus, costs other than revenue foregone would decrease to $\$8\ 520$ (20 percent less than $\$10\ 650$). Total cost of this alternative would be $\$20\ 520$ ($\$8\ 520$ plus $\$12\ 000$).

The second alternative which meets the sediment discharge requirements consists of establishment of 40 m filter strip in which no machines are allowed. All commercial timber (i.e., 300 m^3 per ha) on this 6.4 ha filter strip can be cut but must be winched out at a higher cost. On the 6.4 ha of the filter strip costs are estimated to be $\$8\ 094$. For the remaining 13.6 ha costs will drop to an estimated $\$7\ 242$ to reflect reduction in area logged. Thus, total cost of this alternative will be $\$15\ 336$.

Assuming that these are the only two alternatives considered that meet the sediment discharge restriction, we would choose the lowest cost alternative or the filter strip approach. Revenue would be \$60 000 as before and cost would be \$15 336, for a net return of \$44 664, which compares with a net return of \$39 480 in the buffer strip alternative. The information generated in this analysis further indicates that the cost of the sediment discharge restriction would be \$49 350 minus \$44 664 or \$4 686.

Example No. 2: Economic Analysis of a Watershed Protection and Management Project ^{1/}

Background on Project

Project Title:

Watershed protection for the Sierra Reservoir.

Project situation:

Some years ago a reservoir was built along the Sierra river to provide storage of water for downstream use during periods of low flow. Downstream uses include irrigation on some 9 500 ha and domestic water use by the local population. It has been found after five years of operation that the reservoir is silting in at a much faster rate than initially anticipated, thus reducing effective capacity and ability to meet water requirements downstream. Siltation is occurring at a rate of 4 million m³ per year. Present reservoir capacity is down to 100 million m³. At the present rate of siltation, it will only be four years before capacity is reduced to a point where it can no longer meet estimated water requirements of downstream users. (Domestic water use is increasing at a rate of about 6.19 percent per year, while irrigation use is fairly constant.)

Project goal:

To prevent the reduction (or loss) of water related downstream benefits, ^{2/} the project would extend the effective capacity and life of the reservoir by reducing the rate of siltation from 4 million m³/yr to 1 million m³/yr. ^{3/}

Project points of view

- (a) Downstream users of water have a direct interest in maintaining the capacity of the reservoir so that they can continue to receive water during the dry periods when river flow is inadequate to meet requirements;
- (b) Upstream users of the land which would be affected by the various conservation measures proposed for the project are interested in how such measures would affect them. If effects are negative, some form of compensation may be included in the project plan;
- (c) The nation at large is concerned with increased crop consumption, improved welfare of domestic water users, and losses or gains incurred by upstream land users.

The point of view adopted in the analysis is primarily that of the nation, although the other two viewpoints are also considered.

1/ Adapted from a project in the Andean foothills of a South American country.

2/ The benefits that would be lost without the project include crop values and health and satisfaction associated with domestic water use.

3/ Since there was apparently no problem of flood damage with or without the project, flood prevention was not included as a goal. It could be added in as a goal and treated in exactly the same way, if it was a problem.

Identification and Valuation of Project Costs

To accomplish the project goal, the following project components have been proposed in the technical design and analysis:

- (1) Establish protection forest on the most critical areas where no other activity should take place because of slope or critical nature of soil protection.
- (2) Establish protection/production forests on areas that need permanent protection but which are less critical so that some forest utilization can take place on a controlled basis.
- (3) Build terraces on some of the most critical areas with very unstable soils.
- (4) Manage and maintain pasture lands on a rotation, based on their carrying capacity and ability to regenerate. This will primarily involve control and policing activities together with technical assistance.
- (5) Establish forest management on existing natural forest areas. This would include control on harvest and other activities, watershed protection inputs into access road establishment, inventory and other information gathering activities.
- (6) Establish an overall watershed management and administration unit within the regional government to supervise and control implementation of an integrated watershed management programme for the whole watershed, including the above elements. Include extension services for local farmers.

In the project documentation, appropriate technology, input requirements and timing for each of the project components were analysed. Based on an initial survey of the total watershed of 17 500 ha, the scale of each of the project components was determined, as shown in Table 1. Average input requirements per ha were estimated and applied to the total areas to arrive at total labour, equipment, and other input requirements. These input requirements together with unit value estimates were then used by the economist in valuing the project costs, which are summarized on lines 4 through 8 of Table 4.

In developing economic values for inputs, only unskilled labour was shadow priced. Other inputs were valued in the economic analysis at their financial or market price values.

A project period of 26 years was considered appropriate, considering the relevant social discount rate of 12 percent. 1/

1/ For discussion of choice of project period (see EAPP).

Table 1

Areas associated with each project component

Component	Hectares
Protection plantings	760
Protection/production plantings	870
Terraces	320
Pasture use control	3 850
Natural forest management	3 160
Watershed planning & Adm.	(17 500) 1/

1/ Including the parts of the watershed not requiring direct action.

Identification of benefits

Reservoir demand (i.e. the demand on water from the reservoir which would not be available without it) ^{1/} is estimated at 86 million m³ in the first year (year 0) of the project as shown on the first line of columns 5 or 6 of Table 2. The capacity of the reservoir is 100 million m³ at present (start of project) and is decreasing by about 4 million m³ per year due to siltation. (See Col. 2 of Table 2. Thus, in about four years from the present the estimated capacity of the reservoir without the project would just be equal to demand. From then on, the reservoir would not meet the requirements for water from it.

With the project, it is estimated that the rate of siltation can be reduced to about 1 million m³ per year. Thus, the reservoir will be able to meet requirements for a longer period of time, although eventually, even with the project, demand for water will outstrip the capacity of the reservoir. (This will occur in year 10. Compare Cols. 3 and 6).

A first reaction might be to use the difference between the without and with project capacities as shown in Col. 4 as a measure of benefits. However, this would overstate benefits, since even without the project, the reservoir could satisfy demand for four more years. With or without the project, the benefits would be the same during those first four years and, thus, the benefits due to the project would be zero during that period (years 0-3). For the next six years (years 4-9) capacity with the project would still be above demand. Thus, with the project, the benefits due to the project for this period would be the difference between estimated demand and supply without the project, or the demand deficit which would start to be felt in year 4 if the project were not undertaken. (This is the difference between row items in Cols. 5 and 6). In year 10 demand would start to outstrip supply even with the project. Thus, from year 10 and on to the end of the project, the appropriate benefit figures would be the differences in capacity with and without the project (i.e. the difference between cols. 2 and 3). Using the above approach, the increased water use due to the project is identified and shown for each year in Col. 7 of Table 2.

The figures shown in Cols. 5 and 6 are gross figures which include evaporation from the reservoir. Since the evaporation would be approximately the same with and without the project, there is no need to adjust the figures shown in Col. 7. They represent net increases in effective water use.

In addition to the direct benefits associated with increased reservoir capacity, there will be some timber related benefits from the combined production/protection plantings. Based on experience elsewhere, these are expected to be as shown in Table 3. In years 6 through 10 there will be some minor thinning volumes available and in years 17 through 21 there will be final harvest volumes available.

In addition to the water and timber related benefits, the following indirect benefits were identified but not quantified in the study:

- (a) Eventual increases in livestock production due to regulation of grazing on watershed lands. (At present, many of the pastures are marginal due to overgrazing). The project would restore these lands.
- (b) Aesthetic values will increase as the land is rehabilitated.

^{1/} i.e., release of water in dry season to meet requirements during that period. It does not include the water used that would have been available without the reservoir, i.e., the requirements which would have been met from normal precipitation and river flow without it.

Table 2 - Watershed Project: Identification of Water Benefits

(1) Year	(2) Reservoir without project	(3) Reservoir Capacity with project	(4) Difference with & with- out project	(millions of m ³ /yr)			(7) Difference in use with & without 3/
				(5) Reservoir Use without project 1/	(6) with project 2/		
0	100	100	0	86.0	86.0	0	
1	96	99	3	86.4	86.4	0	
2	92	98	6	86.8	86.8	0	
3	88	97	9	87.2	87.2	0	
4	84	96	12	84	87.7	3.7	
5	80	95	15	80	88.2	8.2	
6	76	94	18	76	88.7	12.7	
7	72	93	21	72	89.2	17.2	
8	68	92	24	68	89.8	22.8	
9	64	91	27	64	90.4	26.4	
10	60	90	30	60	90	30.0	
11	56	89	33	56	89	33	
12	52	88	36	52	88	36	
13	48	87	39	48	87	39	
14	44	86	42	44	86	42	
15	40	85	45	40	85	45	
16	36	84	48	36	84	48	
17	32	83	51	32	83	51	
18	28	82	54	28	82	54	
19	24	81	57	24	81	57	
20	20	80	60	20	80	60	
21	16	79	63	16	79	63	
22	12	78	66	12	78	66	
23	8	77	69	8	77	69	
24	4	76	72	4	76	72	
25	0	75	75	0	75	75	

1/ Constrained by demand for water during first 4 years then constrained by capacity as demand outstrips supply

2/ Constrained by demand for first 10 years then constrained by capacity as demand outstrips capacity even with the project

3/ This is the measure due to the project, i.e. the difference in use with and without the project

Table 3 - Inputs and Outputs - Production Forest Component

	0	1	2	3	4	5	6	7	8	9	10	11-16	17	18	19	20	21
Ha planted	174	174	174	174	174							174	174	174	174	174	174
Thinning harvest																	
ha																	
	174	174	174	174	174												
	20	20	20	20	20												
	3480	3480	3480	3480	3480												
Total m^3																	
Final Harvest																	
ha																	
	174	174	174	174	174												
	525	525	525	525	525												
	91.3	91.3	91.3	91.3	91.3												
Total m^3 (1000)																	

- (c) Access roads required for protection and other watershed management activities will permit faster and cheaper access by farmers to markets and increased mobility for extension personnel so they can reach more farmers.
- (d) The project is expected to result in an increase in water quality in addition to quantity. A reduction in suspended loads carried over the reservoir dam will decrease the need for maintenance on individual irrigation installations.

Valuation of benefits

Based on studies of crop increases made possible by irrigation, it was estimated that irrigation water flowing out of the reservoir would return a net of P2 per m³ of water ^{1/}. Since (1) the major portion of the water is used for irrigation, (2) there was no feasible way of placing a value on the water used for domestic purposes, and (3) there is no feasible way of allocating the increased water made possible by the project to irrigation and domestic use, it was decided to value the domestic water at the rate used for irrigation, namely P2 per m³. This was recognized to be a conservative estimate. Using this value per m³ and the water increase figures in Col. 7 of Table 2, the corresponding annual water related benefits from the project were determined as shown in row 1 of Table 4.

The wood production benefits were valued at P290 per m³ on the stump. This value was a parity price based on the value of imported wood. ^{2/} The parity price was adjusted down by 10 percent to reflect the lower quality of project wood. Total wood production benefits are shown on line 2 of Table 4.

Other benefits were not valued due to inadequate data or to the inappropriateness of attempting to quantify values, e.g., for the aesthetic benefits.

Comparing costs and benefits

As indicated on line 9 of Table 4, there is a net cost involved in the project for the first four years, after which the value flow turns positive and increases steadily over the life of the project. Using a rate of discount of 12 percent, we arrive at a Net Present Worth (NPW) for the project of some P292 million. ^{3/} The rate of return (EROR) of the project would be well in excess of 50 percent.

The high returns to this project can be explained quite easily. Since the reservoir was already in place and its cost represented "sunk costs", they were not included in the analysis of the project. Thus, the small amount of additional expenditure required for the watershed protection activities (the project) were compared with the returns which actually include the total incremental benefits from the reservoir. Obviously, if one were analysing a new reservoir project, the situation would be quite different, since the substantial expenditure for the reservoir would have to be added into the cost stream for the project, while the benefits would remain approximately the same.

^{1/} i.e., after subtracting from final crop value all costs back to the reservoir, e.g., farming costs, marketing, water distribution, etc., but excluding any sunk costs.

^{2/} The approach used to derive such parity values is described in EAFP.

^{3/} The rate of discount was given to the project planners by the national planning office and represents the rate used for evaluating all public projects in the country.

Table 4 -Value Flow Table
(millions of pesos)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
BENEFITS																											
1 Irrigation & domestic use	0	0	0	0	7.4	16.4	25.4	34.4	45.6	52.8	60	66	72	78	84	90	96	102	108	114	120	126	132	138	144	150	
2 Wood production						1.0	1.0	1.0	1.0	1.0								26	26	26	26	26					
3 Total	0	0	0	0	7.4	16.4	26.4	35.4	46.6	53.8	61	66	72	78	84	90	96	128	134	140	146	152	132	138	144	150	
COSTS																											
4 Planting protection forest	3.4	4.5	1.1																								
5 Planting production forest	1.3	1.6	1.6	1.6	1.6	1.6	0.3																				
6 Terrace construction	0.8																										
7 Management costs ^{1/}	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
8 Total	6.5	7.1	3.7	2.6	2.6	1.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.3	2.6	2.6	2.6	2.6	1.3	1.0	1.0	1.0	
9 NET BENEFIT (COST)	(6.5	7.1	3.7	2.6)	4.8	15.1	25.4	34.4	45.6	52.8	60	65	71	77	83	89	95	125.4	131.4	137.4	143.4	149.4	130.7	137	143	149	
10 Present Value at 12%	(6.5	6.3	2.9	1.8)	3.0	12.9	12.9	15.6	18.4	19.0	19.3	18.7	18.2	17.6	17	16.3	15.5	18.3	17.1	15.9	14.9	13.8	10.8	10.1	9.4	8.8	
11 NPW at 12%																											

^{1/} including protection and extension services, maintenance and administration

3. DISCUSSION OF ISSUES

The two examples presented are representative of the types of economic analysis one encounters for watershed related projects. The following discussion outlines some of the major issues which arise concerning these examples and points to watch when applying the guidelines presented in EAFF to watershed related projects.

3.1 Considering Alternative Means for Achieving Project Goals

One of the basic points made in EAFF is that project planners should explore alternative means for achieving given project goals. If only one alternative is presented to the decision-maker, his only decision is whether to accept or reject it. On the other hand, if information is presented which permits him to look at a range of alternative means for achieving a goal, then he can more thoroughly consider and weigh the implications of different courses of action.

In Example 1 two alternatives to the standard logging approach were considered explicitly in the analysis. If other known alternatives had been available then they should also have been considered. In this case, the objective was to find the lowest cost alternative that met the maximum allowable sediment discharge restriction or constraint. Thus, one should note that costs and benefits for the standard logging approach were used only as a basis for comparison since it was, by definition, an unacceptable alternative due to the fact that it did not meet the constraint. Thus, actually only two alternatives were compared, the buffer strip one and the filter strip one. If others had been available (technically defined), they could very easily be included in the analysis.

The appraisal did not consider alternatives in the case of Example 2. However, there appear to be two which might have been considered. The first is the use of dredging at some future date to maintain reservoir capacity equal to demand. The second is the expansion of the reservoir to increase capacity so it can meet demand even when siltation occurs. In addition, the report on which this example is based did not discuss alternative technologies and scales for project components, nor did it go into the relative advantages of alternative timings of project activities to more efficiently achieve the goal of the project. Finally, although some of the project components were separable in terms of costs, the analysts did not have information on which to base a separation in terms of benefits. Thus, components were analysed separately and it was not possible to evaluate alternative combinations of project activities to find a more efficient overall solution for meeting the goals.

Based on the information available to the authors, it is difficult to state whether, in fact, additional alternatives were explored in the early stages of designing the project described in Example 2. However, the point to be emphasized here is that alternatives should be considered and that there should be an economics input at the early stage of project identification and formulation of alternatives. In other words, if possible, project planners should avoid discarding alternatives at an early stage on purely technical grounds. What may appear to be an inferior alternative to the technical expert may not be so from an economic point of view, given relative factor costs existing in the country in question. Initial - albeit rough - economic calculations can be extremely useful in terms of judging the initial set of alternatives and limiting them to those which will be studied in greater detail.

3.2 Determining Project Scope and Context

A major question facing project planners is what to include and what not to include within the scope of a given project.

From a practical point of view, it boils down to a question of where to cut off the endless chain of effects or impacts associated with a given project. The theoretical answer is: "Include all the impacts." The practical answer is: "Include all those impacts which you can identify and which appear to be large enough relative to the direct and immediate impacts to make a difference in the cost and benefit flows." The objective of a project evaluation is to generate the information needed to make a sound decision as to whether or

not the project has benefits exceeding costs and, if so, whether the benefits exceed the costs by a large enough margin to make it worthwhile to commit scarce resources to the project rather than to some alternative use. If the direct benefits associated with a project are large enough relative to costs to make the project worth undertaking from an economic point of view, then spending a large amount of effort and funds on further analysis of all the various indirect impacts will not be worthwhile. However, if the project is marginally unacceptable, then there is a much stronger case for detailed analysis of indirect impacts. No general guidelines can be put forth here on how to determine the appropriate cutoff for considering indirect impacts. That will depend on each project situation, the knowledge of the project planners and staff specialists, the cost and time involved in generating information on indirect impacts, and the objectives of the institution sponsoring the analysis.

In the case of Example 1, the scope was very narrow, mainly due to the fact that the project involved a very small area and probably had insignificant indirect impacts. The example illustrates well the type of brief, uncomplicated analysis associated with operational decisions. Once this particular situation had been analysed and the best logging method chosen (the lowest cost method that met the constraint) it is likely that that method was accepted and used for other similar logging situations without further analysis, i.e., this simple analysis served as the basis for developing an operational guideline for logging that says: "In situations of river side logging, a filter strip system is the cheapest alternative logging system which meets the specified maximum allowable sediment discharge constraint."

In the case of Example 2, the project scope included the major impact elements, with the exception that there was no consideration given to how the project would affect the farmers upstream on the watershed lands who would have to change their operations due to conversion of land to forest or due to curtailment of grazing on critical watershed lands. Similarly, there was no quantitative analysis of the positive impacts on farm economies associated with the improved road network and the increased mobility and availability of extension services. Ideally, these should have been included in the analysis, and one would expect - even without having information on the project background and area - that it would have been possible to provide some more explicit treatment of these impacts.

The question of project scope is closely related to other aspects of project definition: (1) project points of view, and (2) cost and benefit identification.

Concerning project points of view, Example 1 can be identified with two: the logging operator (or company involved with logging the area), and the public point of view concerning sediment discharge. In this case, the public point of view has been expressed in terms of the maximum allowable discharge regulation and thus does not need to receive further consideration in the analysis.^{1/} The logging operator or company point of view (assuming that this is a private entity involved) is really the point of view from which the analysis is carried out, i.e., the question is: "What is the minimum cost we have to incur to achieve the constraint?" If the public sector is doing the logging, the question remains the same from an economic efficiency point of view.

Example 2 is somewhat more complex in terms of points of view. As stated in the text, there are three points of view identified, namely the downstream water users, the upstream land users and the national point of view which incorporates the other two points of view within an overall objective function.^{2/} The downstream users' point of view defines the scope of the project at that end: the project should be defined broadly enough to include the necessary downstream costs to achieve the benefits accruing to the downstream users.

^{1/} Unless, of course, the analyst is also asked to look explicitly at the costs and benefits associated with different levels of sedimentation. This, however, is a separate question.

^{2/} As mentioned in EAFF this objective function relates to project impact of aggregate consumption.

On the other hand, the upstream land users' point of view defines the scope of the project at that end: the project should be defined broadly enough to include those costs and benefits for that group that occur because of the project. As mentioned earlier, there did not appear to be adequate consideration given to this point of view and the associated costs and benefits.

Consideration of points of view helps the analyst in identifying the appropriate scope and in identifying relevant costs and benefits for use in the economic, financial and social analysis of the project. The following two sections discuss cost and benefit identification in terms of economic efficiency analysis.

3.3 Identifying Costs

One can specify three main categories of costs involved in watershed projects. These are:

Structures and work costs: These include costs of dams, gully plugs, construction of contour furrows or terraces, channel construction or improvement, road relocation, retainer walls, etc., and maintenance of these structures and facilities.

Vegetation manipulation costs: These mainly include costs of removal of vegetation and planting and management costs associated with the establishment of new vegetation.

Value of outputs foregone: Even eroded or deteriorated lands may be producing values through grazing, subsistence farming, etc. These activities may have to be curtailed for a period of time in order to restore land to some higher level of productivity. The value of such production foregone should be included as a project cost. In the case of a protection project, timber harvested per unit area may be reduced due to the introduction of buffer strips along rivers, streams, roads, etc. Selective harvest may have to be imposed on steep hillsides which may in turn reduce the present value of harvests. This reduction is a cost.

The first two categories of costs are quite obvious, and both examples in Section 2 treated these in an adequate fashion. The third category - value of outputs foregone - is also relevant to both cases. In Example 1, it can be noted that the analyst treated the value of timber foregone through creation of a buffer strip as a cost. He could also have merely reduced the total benefit figure by this amount, thus treating this value foregone in terms of benefits. Either way would have produced the same result, since the objective was to arrive at the alternative with the highest net return.

In the second example, there were values of outputs foregone from changes in land use that should have been considered but were not, as explained in the previous section. This supports the point made earlier that project scope points of view and cost and benefit identification are closely interrelated. Since the upstream land users' point of view was not adequately defined, the analyst also missed identifying explicitly changes in value of output associated with upstream land use due to restriction of grazing on some lands and shift in land use from agriculture to forestry on other lands.

In identifying costs (or project inputs) it is essential that the "with and without" test be applied. Basically, this means that the analyst asks and answers the following question: "What would the situation likely be without the project over the period of years considered for the project and what would the situation likely be with the project?" Only the difference should be attributed to the project. This approach applies to both costs and benefits (inputs and outputs). The particular point to emphasize here is that the "with" and "without" project comparison is not the same as the "before" and "after" project comparison for most types of watershed projects. It is likely that the situation as it exists before the project is introduced, would change over the life of the project; and it is necessary to estimate how the situation would develop over time without the project, since only the difference between costs and benefits without and with the project can be attributed to the project.

For example, in the case of costs, one might be tempted to include as part of a larger watershed improvement project the maintenance costs for a road system that is being affected by erosion processes as a cost. But, assume that the road is essential to the communications of the region in question and, regardless of whether or not the project is

undertaken, the road would have to be maintained and kept open for the region. Thus, the road maintenance would be undertaken with or without the broader watershed improvement project. In this case, the costs of road maintenance should not be included as a project cost. If, with the project, the road maintenance costs can be reduced, then this reduction in costs should be included as a benefit due to the project.

Similarly, assume that the present level of use of a given land area will have to be curtailed as part of an overall watershed protection project. As mentioned above, the value foregone due to this reduction in use should be treated as a cost. But suppose that use of the land would have increased over time without the project. Then the analyst will have to estimate what that increase in use would have been in order to arrive at correct estimates of the costs, due to impact of the project on use of the given area of land.

3.4 Identifying Benefits

Similar arguments stated above apply to benefits. For example, over time, without the proposed watershed project, soil conditions might deteriorate, erosion might increase, etc. The analyst has to make sure that these changes are taken into account. Figure 1 illustrates a typical situation. As noted, at time 0, production is at level X. Without the project, conditions would deteriorate until in year n production would have decreased to Y. With the project, it is estimated that production will increase to Z. The point to note here is that both Z minus X and X minus Y are legitimate benefits to be attributed to the project. Thus, the analyst will not only need to estimate the increase in production which will be possible (i.e. Z-X), but he will also have to make an estimate of the losses which will be avoided (i.e. X-Y). Example 2 illustrates this point.

Application of the "with and without" test also brings out another point related to benefit identification and valuation (which is also illustrated by Example 2). The point is that merely because a project changes some physical dimension in a positive way, this does not necessarily mean that there is a benefit involved. In Example 2, the project starts immediately to reduce the level of siltation in the Sierra reservoir and thereby increases the effective capacity of the reservoir. However, even without the project the level of capacity of the reservoir is in excess of demand and will continue to be so for the next 4 years (see Table 2). Applying the "with and without" test, the analyst can see that consumption of water (the relevant benefit parameter) will remain the same with or without the project for this period (see Cols. 5 and 6, Table 2). Thus, the benefits (losses avoided) due to the project will be zero during the first four years, or until the capacity of the reservoir without the project would have fallen below requirements for water. This point applies more broadly to many different types of watershed projects.

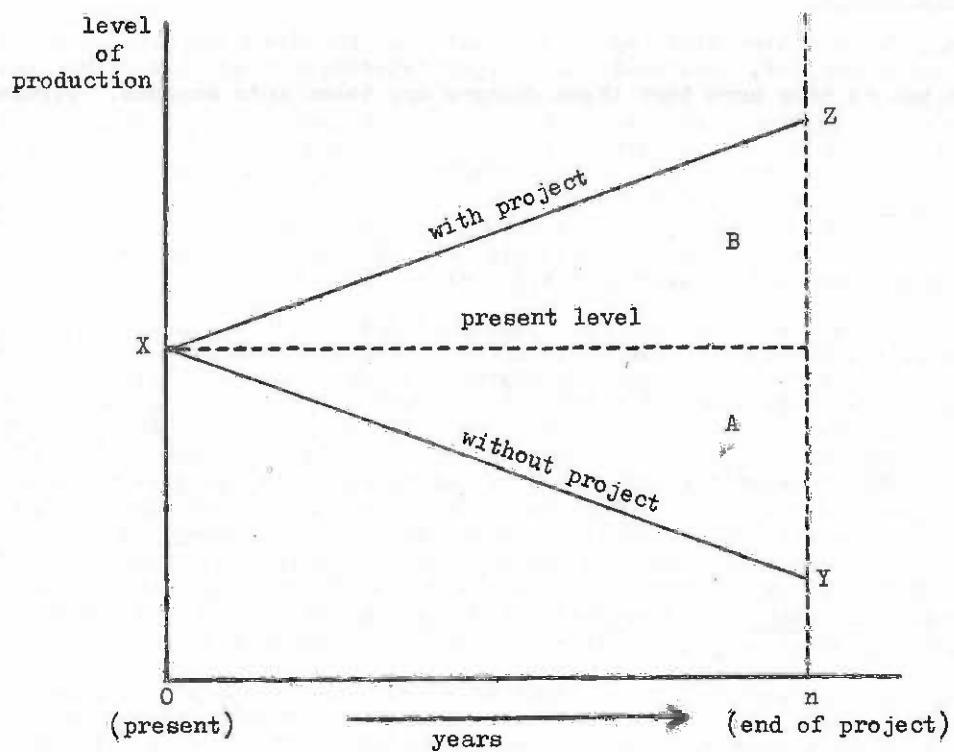
The above point relates to the fact that in an economic efficiency analysis, benefits have to be measured in terms of human consumption. Thus, for example, the hydrologist may provide an estimate of tons or cubic metres of soil loss that can be avoided by undertaking a given project. But this information is not enough for an economic analysis. In order to value the benefits from the project, such losses avoided have to be translated into a schedule of crop or other consumption losses avoided. Thus, agricultural experts have to come up with a relationship between soil loss and crop production or soil loss and production of some other consumption item. This consumption loss can then be valued and used as the benefit in the economic efficiency analysis.

Most hydrology projects are undertaken by the public sector, the main reason being that "water" is seldom sold in the market place. While farmers using irrigation are often required to pay some amount for water they use, and households and industries often pay a nominal fee for domestic and industrial water, in general water is not priced in the market in the traditional sense.^y Thus, measures of willingness to pay for water, which are the appropriate measure of the value of benefits in an economic analysis, are seldom available (see EAFF, Chapters 2 and 5). Similarly, many of the inputs required for hydrology projects are often not priced in the market. Thus, it becomes necessary to estimate shadow prices for such non-market priced benefits and costs. We mention this issue here, since it is important in the economic analysis of watershed projects. However, the process of shadow pricing is rather complicated and is discussed elsewhere. The reader is referred to detailed treatment of the subject in EAFF and in a recent work done for the Organization for Economic Cooperation and Development.^{2/}

^y I.e., water prices are administratively set and not determined on the basis of the interaction of supply and demand.

^{2/} See OECD (1979)

Figure 1



A = losses avoided

B = production increases over present level.

3.5 Treatment of Benefits and Costs in Multiple Purpose Projects

A point worth mentioning here is the need to use care and caution in identifying costs and benefits associated with multiple purpose projects which include a watershed management element. For example, in some cases, trees planted on denuded lands as part of a watershed protection or restoration project will also be managed for controlled harvest for fuel or other products. In such cases, both types of benefits will have to be included in the analysis. ^{1/} Proper allocation of tree planting costs to the watershed benefits and the wood output benefits is difficult. If timber production is the main objective of the project with watershed protection or restoration as a secondary purpose, then one practical approach would be to allocate the basic costs to the timber objective. Any additional costs of vegetation management to achieve the constraint or watershed objective would be allocated to the watershed component of the project. Similarly, in the case of logging, road redesign to meet certain watershed constraints or objectives, the equivalent of the minimum road cost to get the timber out would be attributed to the timber element, while the additional costs associated with higher standards to meet the watershed objectives would be allocated to the watershed element.

In the case of a primary purpose watershed project, the cost of tree planting or other activities would be associated with the primary purpose and benefits, while timber benefits would be treated as secondary benefits. As mentioned earlier, it is important in such cases to remember to subtract any secondary costs associated with the timber production up to the point of valuation of the timber (e.g., stumpage level, delivered log level, etc.).

3.6 Timing of Costs and Benefits

Most watershed projects tend to be longer term projects in the sense that the inputs occur over a considerable period of time and the benefits accrue over an even longer period of time. Further, benefits and costs are constantly changing over time.

A main problem is to develop a sound estimate of the timing of the benefits. Restoration projects generally take time to implement. Full productivity is restored slowly in most cases. For example, if trees are planted on a deteriorated watershed, the full protective effect on erosion control will take some time to achieve.

In order to keep track of the project assumptions regarding the build-up to project benefits and costs over time, it is essential to use appropriate physical flow tables and, ultimately, properly designed value flow tables. (Such tables are shown as Tables 3 and 4 in Example 2 in this paper.)

3.7 Treatment of Uncertainty

Watershed related projects are particularly subject to great uncertainty in terms of the values of costs and benefits used. Thus, it is important that project appraisals include explicit treatment of uncertainty. Neither of the two examples presented earlier did so, and that is perhaps a typical situation found in most economic appraisals.

There are some simple techniques, such as sensitivity analysis and break-even analysis, which can be applied rather easily and cheaply in most cases. Basically, sensitivity analysis involves varying assumptions concerning the values of key parameters and then testing the sensitivity of the chosen measures of project worth to such changes. A breakeven analysis is aimed at identifying values of key parameters which would switch the profitability of a project from acceptable to unacceptable levels.

^{1/} Of course, any associated costs involved in harvest will have to be subtracted, if roadside value for the harvest is used instead of stumpage value.

4. REVIEW OF UNITED STATES LITERATURE

The previous section provided a general view of some of the main problems to watch for in carrying out an economic analysis of a major purpose watershed project or a project which includes water related considerations as constraints. In the present section, a brief review is provided of some of the most relevant work done in the United States dealing with watershed project economics.

The need for watershed management practices developed in the United States largely because of erosion, sedimentation, and flooding which resulted from (a) overgrazing of western rangelands, (b) uncontrolled wild fires and (c) careless logging operations (Bailey and Croft, 1937; Trimble and Weitzman, 1953; Haupt, 1959; Rice *et al.*, 1963; Packer and Christensen, 1964; and Packer, 1967). Thus early watershed management practices were synonymous with protection and restoration (Packer and Laycock, 1969). The protective influence of vegetation on the processes of erosion, flooding and sedimentation has been recognized for some time. The effects of vegetation and land management activities on water yield, on the other hand, has been a subject of considerable misunderstanding. Early thinking on this matter suggested that because dense forested watersheds were headwater areas of most flowing streams and rivers, such forest cover was essential to the production of water (Satterlund, 1972). Experimental evidence has suggested just the opposite. Forest vegetation consumes large quantities of water by means of transpiration. This results in a loss of water to soil moisture and streamflow. The inference from such knowledge is that forest harvesting or vegetation removal in general will tend to increase water yield. This stimulated watershed research throughout the United States (Hoover, 1944; Dortignac, 1965; Hibbert, 1965). The possibilities of watershed management directed towards increasing water yields had important implications to land management in the water-poor regions of the United States.

Regardless of whether goals of watershed management are to protect or to increase the water resource, or both, the first step in economic analysis is to determine distinctive production functions for various management practices (Lloyd, 1969). Several examples of physical relationships or production functions are discussed below in terms of the following broad management goals: (1) watershed protection and (2) watershed restoration and water yield improvement.

4.1 Watershed Protection

Vegetation protects soil from the energy of raindrop impact, minimizes overland flow, and along with the soil-binding benefits of root systems on steep slopes, reduces erosion, sedimentation and nutrient losses from watersheds (Satterlund, 1972; UNESCO).

1972). Conversely, substantial removal of vegetation by fires, shifting cultivation (agricultural expansion), timber harvesting, grazing, road construction, or urbanization, can increase soil disturbance resulting in soil and nutrient losses from the watershed, sedimentation of downstream receiving waters, and more frequent occurrence of floods. Packer and Laycock (1969) summarized impacts of a variety of land uses and indicated that the density of plant and litter cover were the most important factors affecting soil erosion and overland flow on range lands. In forestry, poor construction of logging roads and improper skidding practices can be major causes of erosion and sedimentation.

Because of the undesirable consequences of livestock overgrazing, overpopulations of wildlife, poor road construction, improper skidding practices, extensive wildfires, excessive recreation use and related activities, land management agencies have developed guidelines to minimize adverse impacts. In some cases, such guidelines are imposed by law. Limited cause-and-effect relationships and hydrologic information are usually available to establish these guidelines for a specific area. Typically such guidelines are based on experiments from a few intensively studied watersheds. Such guidelines usually result in regulations concerning the maximum slope and location for logging roads, rules for building roads in proximity to water courses, and requirements for the maintenance of buffer strips of vegetation along water courses to reduce sedimentation of streams (Lantz, 1971; U.S. Department of Interior, 1970). In some cases (e.g., Korea) land use laws establish maximum slopes on which land clearing can take place.

4.2 Erosion, Sedimentation and Flooding

Erosion and sediment control methods used in eastern and western areas of the United States have been evaluated by Thronson (1973). Cost data were applied to theoretically predicted soil losses. Over 25 control methods were examined. The principal cost elements consisted of labour, equipment and materials. Costs per cubic yard of soil retained by conservation methods were compared with costs of several methods of sediment removal in stream channels and reservoirs. Annual cost figures were based on control effectiveness and economic life of each project. Sediment removal was in general found to be more costly than erosion control. Associated costs such as fisheries habitat damage and loss of site productivity would be important but were not quantified here. In order to identify both direct and indirect costs associated with watershed maintenance or restoration projects, specific examples or case studies will be discussed.

The annual fire-flood phenomena in southern California illustrates the importance of maintaining deep-rooted vegetation, in this instance chaparral, on steep mountainous slopes. Frequent fires in the chaparral watersheds above the densely populated areas result in severe flooding and erosion (Rice *et al.*, 1963; Corbett and Rice, 1966; Packer and Laycock, 1969). The adverse economic consequences of such fires have been used to justify extensive contour-furrowing and contour-trenching and seeding to minimize runoff and erosion and to speed up the reestablishment of a vegetative cover. Such mechanical or structural solutions, although costly, are often the only effective means to rehabilitate severely eroded, steep-sloped watersheds. The costs associated with fire prevention and other management should be measured against losses of watershed productivity, costs of sedimentation and losses of life and property in addition to reclamation costs.

Overgrazing of high elevation watersheds in northern Utah caused substantial mud-slides and debris-laden floods that resulted in substantial losses of property and life (Bailey and Croft, 1937; Bailey and Copelund, 1961). These watersheds were subsequently contour trenched and revegetated. Considerable success was achieved in containing erosion and to a certain extent, in reducing flash floods. In this example, as with the fire-flood problem in southern California, the benefits derived from proper watershed management cannot be entirely quantified in economic terms. For example, values of human lives saved and wildlife habitat and esthetics damage avoided, cannot readily be quantified.

In some instances natural levels of erosion and sedimentation are excessive and cannot be controlled with watershed maintenance or restoration projects. Such was the case in southeastern Utah where considerable contour furrowing, gully plug emplacement and range reseeding had little impact on erosion and sedimentation (Workman and Keith, 1975). The area had been overgrazed in the past, but the extremely high levels of natural or geologic erosion minimized the impacts of rehabilitation efforts. The purpose of this project was to establish a more dense vegetative cover to reduce sedimentation of the lower Colorado River and thereby extend the life of Lake Powell and Glen Canyon Dam. Benefits in terms of a reduction in municipal water treatment costs downstream of the project were also evaluated. The project costs averaged US\$5.45 to US\$13.31 per acre and had project lives of from 7 to 10 years which resulted in only an 11 percent reduction in sedimentation. Workman and Keith (1975) looked at minimum possible project costs and compared them with maximum possible benefits to provide the project with "every conceivable benefit of the doubt." In this analysis the benefits consisted of (a) avoidance of water treatment costs of downstream communities with an estimated maximum annual value of US\$49 030, and (b) the extended flow of goods and services associated with the extension of the lives of Lake Powell and Glen Canyon Dam, which included irrigation water, electricity, flood control, and recreation. The total maximum annual value of benefits was US\$48 749 030. A benefit cost ratio was then calculated using a 7 percent discount rate to aggregate future benefits in present value terms. The present values of benefits in the absence of erosion control for 200 years was then subtracted from the present value with erosion control. This maximum present value of benefits was then divided by the cost of treating the entire 1 280 000 acres of frail watersheds. A benefit-cost ratio of 0.12 resulted. Thus, restoration treatments on these frail desert soils in the Upper Colorado River Basin would only return US\$0.12 for every \$1 spent on treatment.

Green (1971) investigated economic impacts of grazing on erosion and sedimentation in terms of site deterioration as well as effects on the life of a downstream reservoir in north central Utah. The Joes Valley Reservoir, a US\$7.5 million project with 62 500 acre-ft. storage capacity was designed for 8 500 acre-ft. of dead storage for sedimentation. With an expected life of 100 years, the project was designed to handle sedimentation rates of about 85 acre-ft. per year on the average. Natural levels of sediment production (approximately 22 acre-ft./year) were determined along with livestock carrying capacity-sediment production relationships. Reduced grazing levels of 500 animal unit months (AUM's) and associated range management practices without rehabilitation measures such as furrowing resulted in reductions of 5 acre-ft. of sediment per year. The removal of 5 acre-ft. of sediment from the reservoir would cost US\$6 630 to US\$19 890 which more than compensated for losses of receipts from grazing of 500 AUM's on federal forest lands. The costs of contour furrowing levels needed to reduce sedimentation for an 80-year period were also developed and contrasted to costs of grazing level reduction.

The costs of site deterioration caused by several different logging systems were compared recently by Klock (1976) in the Pacific Northwest. Unit cost figures for different logging systems were considered essential to quantify effects on reduced site productivity as well as effects on sedimentation, water quality in terms of domestic, irrigation and esthetic values, fisheries habitat, and need for control structures and associated seeding of disturbed sites. Costs, although indirect, "... should be added to the direct operational costs when systems of log removal for a particular forest site are evaluated" (Klock, 1976) 1/

Onsite damages of forest lands were estimated in terms of the fertilizer or nutrient replacement needed to maintain productivity. The following approximation for productivity damage assessment (PDA) was suggested:

$$PDA = \frac{\text{Area} \times \text{Erosion depth} \times (\% \text{ total N}) \times A \times B}{\text{Timber Volume Assessed}}$$

where: % total N = percent total nutrient, such as nitrogen in the soil

A = fertilizer conversion rate in pounds of N per pound of fertilizer

B = cost in dollars of fertilizer per pound per acre.

Such data as inches of soil loss (erosion) per activity, biomass productivity estimates, and soil nutrient make-up, essential to such an analysis would probably be limited in most field situations. One could hardly argue with this approach conceptually, however, in terms of evaluating the effects of erosion on forage or timber productivity because of the long time period required for natural processes to replenish essential plant nutrients.

Downstream damages considered by Klock consisted of (a) detrimental effects on salmon spawning stream beds and (b) costs of sediment removal from channels by dredging. Excessive sedimentation not only affects fish directly but also covers spawning beds which may reduce salmon and steelhead reproduction (Brown, 1974). The value of salmon spawning streams ranged from US\$10 000 per acre in Lost Creek, Oregon to as much as US\$3.0 million per acre on the Fraser River in British Columbia (Klock, 1976). Costs of sediment removal on the other hand ranged from US\$0.25 to US\$18.30 per cubic yard depending on method and placement requirements for dredge spoils (see Table 5). A method of assessing sediment costs per thousand board feet of merchantable timber was suggested as follows:

$$\text{Sediment cost} = \frac{\text{Area} \times \text{Sediment Depth} \times \text{Removal Cost}}{\text{Timber Volume Assessed (MBF)}}$$

When considering only yarding effects, Klock estimated that one inch of soil loss created a sedimentation assessment of US\$62.53/1000 bd. ft. of saw logs in one case. This estimate of sedimentation did not even consider road construction which could result in even higher levels. A summary of Klock's results is presented in Table 5.

A closely related and often mentioned benefit of watershed management in addition to those previously described, is flood control. The beneficial influence of vegetative cover, particularly a dense forest cover on overland flow and flooding has been discussed in some detail by Lull and Reinhart (1972) for the eastern United States. In order to quantify such benefits for an economic analysis, a flood damage-frequency analysis before and after removal of vegetative cover by some land use practice should be considered, as accomplished in flood control project evaluations. However, unless large land areas are drastically affected, say by wildfires or extensive clearcuts, the discharge-frequency relationship would show little effect. Even if 30 percent or more of a watershed is

1/ Swanson and McCallum (1969) in a similar study evaluated soil losses from agricultural watersheds in terms of agricultural output-yield reductions.

denuded, the effect on flooding frequency would be expected to be more pronounced for annual maximum peak flows and have little influence on the large destructive floods of 100-year recurrence interval or greater. Hollis (1975) indicated that paving 20 percent of a watershed increased the probability of only small floods of a return period of 10 years or less, but that paving 30 percent could result in a substantial increase in floods with a 100-year return period. Therefore, the percentage of the watershed disturbed is a critical factor in estimating effects on flooding potential.

Harr, *et al.* (1975) found that road construction and poorly designed drainage systems significantly increased peak streamflow when 12 percent or more of watersheds were affected in the Oregon Coast Range. With proper culvert design and bridges in headwater areas, peak flows were not affected. Road construction guidelines as described by Trimble (1959) and USDI (1970) are typically established to reduce erosion and sedimentation which in turn minimizes flooding potential. The costs of higher road standards can be compared to erosion reduction benefits.

A factor that has been observed, yet is difficult to quantify, is the channel constriction process associated with accelerated erosion and sedimentation. Not only does sediment tend to accumulate and diminish the capacity of a channel to transmit flow, but there is a tendency for sediment and debris to build up and form small "detention" dams within a stream system. Such a debris-dam system is perpetuated by several "average" flow years. The consequence of both factors is that when a less frequent but more intense storm and resultant stream discharge occurs, either (1) flood waters escape the sediment filled channel much more quickly than before or (2) the buildup and wash out phenomena of a cascade of sediment and debris dams may accelerate the velocity, increase the total discharge over a shorter time interval, and increase the debris-carrying capacity of the stream. The consequences are greater damages downstream. Therefore, the erosion and sedimentation factors may be important in flood damage from wildland watersheds just as the "quick response" direct runoff which occurs from a denuded watershed.

4.3 Water Quality Considerations

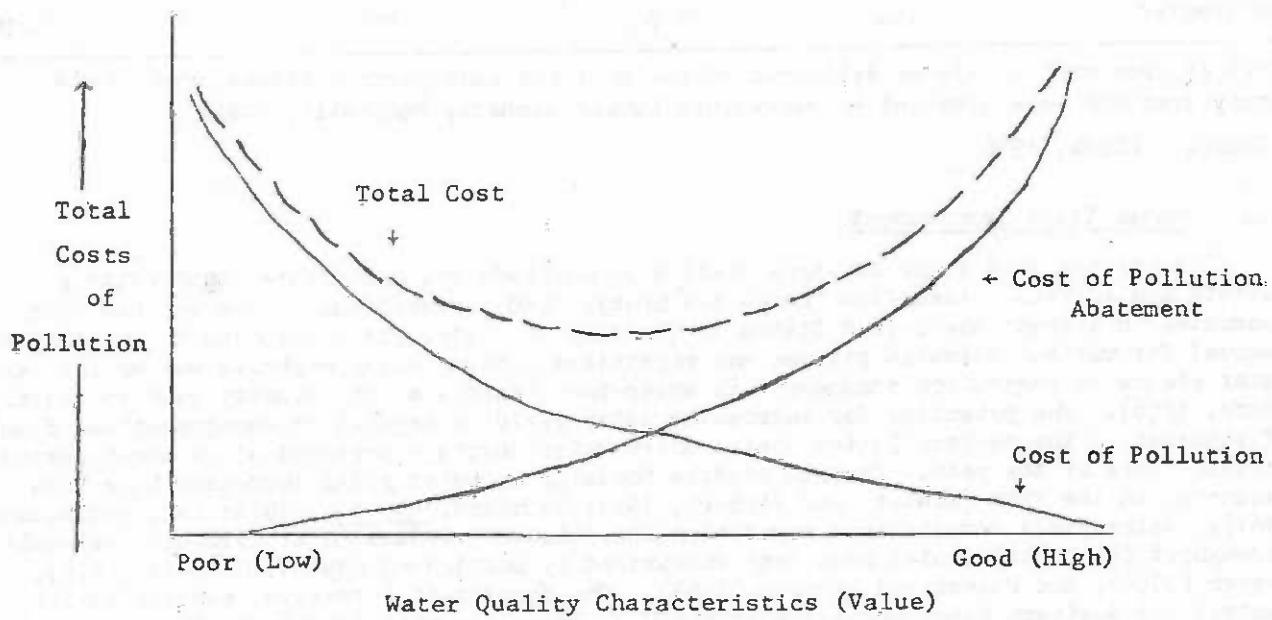
In order to ascertain the benefits of watershed management practices for the purpose of maintaining a high quality water yield, the value of such high quality water has to be estimated. One approach may be to consider the environmental impacts of water pollution from land management practices. Unger *et al.* (1973) considered environmental impacts of water pollution in terms of health, esthetics, and production. The economic consequences of water pollution under the health category include medical service demands, loss of man hours because of illness, human life lost, or the costs of making water supplies safe for human consumption. Impacts on esthetics may be reflected in terms of private property devaluation, alterations of recreation opportunities or social values of "quality of life". Other economic consequences include changes in industrial water treatment costs, changes in types of industries and employment, regional and area dislocations, input costs, income redistribution and final product prices. Jordening and Allwood (1973) also considered both on-site and off-site costs of water pollution. Costs of water pollution were considered in terms of opportunity costs, damage costs and reduced efficiency of productivity or increased production costs. The costs of water pollution were then schematically compared to the costs of water pollution control as illustrated in Figure 2.

For industrial and municipal water quality evaluations the sources of pollutants, technology of water treatment, and costs are easier to evaluate than the "non-point" sources of pollutants from activities on wildland watersheds. Although most previous research has focused on management impacts on erosion and sedimentation, several studies have indicated significant impacts of land use activities on stream temperatures and nutrient levels of receiving waters. (These effects are included in the water "quality" category). Such studies have resulted in the establishment of management guidelines.

"Buffer strips" or streamside vegetation of a specified width have become requirements in timber harvesting operations to minimize impacts on stream temperature as well as sedimentation. Brown and Krygier (1970) reported that removal of streamside vegetation can raise water temperatures above acceptable levels for the survival of salmon and steelhead trout. Maintaining buffer strips along stream channels involves a pollution abatement cost equal to the value of timber withdrawn from harvest and any increased costs of harvest. Dykstra and Froehlich (1976) evaluated stream protection costs in Oregon and found that maintaining buffer strips 55 and 150 feet wide along stream channels resulted in timber volume foregone of 0 to 6 and 6 to 17 percent, respectively. Buffer strip requirements for protecting water quality may result in a significantly larger land base requirement to produce a given volume of timber. Such costs need to be compared with the benefits before deciding on regulations.

Dykstra and Froehlich (1976) also contrasted costs of removing debris from channels following timber harvesting operations with buffer strip costs. The removal of debris from channels following harvesting was reported to cost from \$100 to \$500 per 100 feet of channel, depending on the stream gradient, width and quantity of debris. Such costs represent "costs of pollution" in Figure 2.

Figure 2



Total Cost Determination for Pollution Control
(From Jordening and Allwood, 1973)

Table 5

Some cost estimates of tree removal per 1 000 board feet of merchantable lumber for several yarding systems used in the fire-affected study area

System	Erosion	Direct cost 1/	Indirect assessment Productivity	Sedimentation	Total "cost"
Inches		-----Dollars-----			
Tractor, slopes 0-30%	0.20	34.85	3.30	12.50	50.65
Tractor, slopes 30-50%	.80	34.85	10.60	50.00	95.45
Tractor (over snow), slopes 0-40%	.08	38.60	1.50	5.00	45.10
Cable skidding	1.50	35.00	17.00	93.80	145.80
Skyline (Wyssen)	.04	52.73	.80	2.52	56.05
Helicopter	.04	74.98	.80	2.52	78.30

Cost figures are for timber delivered at the mill for each yarding method used in the study area and were provided by Pack-River Lumber Company, Peshastin, Wash.

Source: Klock, 1976

4.4 Water Yield Improvement

Since the 1928 study at Wagon Wheel Gap, Colorado which indicated that cutting forests can increase streamflow (Bates and Henry, 1928), considerable research has been conducted throughout the United States to quantify the water yield response to vegetation removal for various climatic regimes and vegetation types. Early emphasis was on increasing water yields by vegetation management in water-poor regions of the country such as Arizona (Barr, 1956). The potential for increasing water yield by vegetation management was also of interest in the eastern United States where water shortage problems often occur during certain times of the year. Several studies focusing on water yield increases have been conducted in the East (Hewlett and Hibbert, 1961; Reinhart, *et al.*, 1963; Lull and Reinhart 1967). Water yield results from vegetation manipulation studies on experimental watersheds throughout the United States have been summarized by Dortignac, (1965), Hibbert (1965), Hoover (1969), and Packer and Laycock (1969). The results of intensive research in the central and southern Rocky Mountains by the U.S. Forest Service concerning the potential of water yield increases in all major vegetation types have been documented in a series of "status-of-our-knowledge" reports (Hibbert *et al.*, 1974; Ffolliott, 1974; Ffolliott and Thorud, 1974; Rich and Thompson, 1974; Baker, 1975; Ffolliott and Thorud, 1975; Leaf, 1975a and 1975b; Orr, 1975; Sturges, 1975; and Springfield, 1976). A good information base has thus been established in the Rocky Mountain region which should provide insight into physical relationships and responses to management schemes to allow for economic evaluations of various product-mix alternatives.

Most of the above mentioned studies indicated that reductions in forest vegetation or conversion from deep-rooted species to grass vegetation resulted in increased water yields. Reforestation decreased water yields. Knowledge of water yield responses for all vegetation types and climatic regions has not been determined; however, rough estimates of water yield response can be estimated from previous studies. As Satterlund (1972) indicates a question which needs to be answered before management practices become implemented is "what balance between water and other goods and services is desirable?"

In order to answer such a question, estimates of multiple-use production relationship, including supplementary, complementary and competitive relationships need to be identified and costs and benefits determined for each alternative.

When wildland watersheds are to be managed with increased water yield as a goal, it is essential that water yield responses be evaluated in a multiple use framework. Such an analysis is needed for economic studies because costs and benefits of management schemes cannot be determined if the physical responses (production functions) of such management are not known. As pointed out by Clawson (1974), compatible and incompatible uses of land must be identified and tradeoffs quantified. For example, when the output of one product is increased what effect does it have on other outputs or services. Some of the more recent investigations have attempted to quantify such relationships.

O'Connell and Brown (1972) developed production functions for ponderosa pine watersheds in north-central Arizona by evaluating effects of different levels of strip-cutting on water yield (acre-ft.) wood (bd. ft.), herbage (Lb), and sediment production in tons. The results are summarized in Table 6.

Ffolliott and Thorud (1975) provided an extensive and detailed summary of water yield improvements for the following vegetation zones in Arizona: alpine, mixed conifer, aspen, ponderosa pine, pinyon-juniper, chaparral, grassland, desert shrub, and riparian association. The mixed conifer, ponderosa pine and chaparral vegetation zones were considered to provide the greatest opportunities for water yield increases. Twelve alternatives for state-wide water yield improvement were contrasted. Two of these alternatives are shown in Table 7 for illustration: For each vegetation zone, water yield improvement opportunities as a result of various levels of clearing were examined. In addition, timing and peakedness of streamflow, erosion and sedimentation, water quality indicators, timber, herbage (forage), fish and wildlife, and recreation opportunities were also considered where appropriate. Thus the basic production function elements needed for a product mix evaluation and economic analysis were presented for each vegetation zone.

Even in vegetation zones where water yield (quantity) improvement opportunities do not exist, the management decision should consider impacts on water quality, regimen and soil erosion. Table 8 indicates in general how various land-use or management activities may affect water yield characteristics. Obviously many assumptions are implied, but it may be useful in an initial assessment of components of a multiple product mix for any given area. For economic analysis, however, such relationships need to be quantified both in terms of physical response and in economic value.

Satterlund (1972) discussed earlier work by Worley and Miller (1969) in which only two products, timber and water, were evaluated with the goal of increasing water yield without decreasing timber yield. The product-product relationship for various management alternatives is shown in Table 9. Two outputs, timber and water were contrasted. The basis of selecting the management alternative was that first the alternative must be better in at least some aspect with no reduction in the other. Alternatives 6 and 7 are thus best. The decision to implement 6 versus 7 depends on whether the value of water is worth US\$5.50 per acre-ft. ((US\$3.50-4.50) + (0.40-0.22 acre-ft.)).

Table 6

Estimates of Average Annual Production of Different Levels of Strip Cutting of Ponderosa Pine in Arizona

Production	Percent Strip Cut		
(Avg. Annual Inc. Per Acre)	33	60	100 (clearcut)
Water (ac. ft.)	0.08	0.12	0.16
Wood (bd. ft.)	160	116	36
Herbage (lb.)	150	225	825
Sediment (tons)	0.07	0.04	0.02

Production is average annual increase per acre over the existing management level for a 90-year period.

Source: O'Connell and Brown, 1972

Table 7

Alternative Water Yield Improvement Schemes by Vegetation Manipulation

1.	Mixed conifers - convert 1/3	=	8 273 ac. ft./year
	Ponderosa pine - clear 1/3	=	342 999 ac. ft./year
	Chaparral - convert 40%	=	251 289 ac. ft./year
	Total	=	602 561 ac. ft./year
2.	Mixed conifers - convert 2/3	=	41 370 ac. ft./year
	Ponderosa pine - clear 2/3	=	685 997 ac. ft./year
	Chaparral - convert 60%	=	502 577 ac. ft./year
	Total	=	229 949 ac. ft./year

Source: Ffolliott and Thorud, 1975

Table 8

Relative effects of watershed activities on water yield characteristics

Watershed Management and Related Land Use Activities	Water Yield and Related Characteristics							
	Quantity of Water Yield	Water Quality Indicators				Disease Org. & Colifirm	Flooding Opp.	Timing of Streamflow
		Soil Loss Erosion	Dissolved Temp. Oxygen	Sedi- ment	Organic			
1. Grazing	+	+	0	-	+	+	+	+(?)
2. Timber cutting:								
Thinning	+	+	?	?	?	?	0	+(?)
Clearing	+	+	?	?	?	?	0	+
3. Road construction	+	+	?	?	+	+	0	+(?)
4. Herbicide applications	+	?	+(?)	?	?	?	0	?
5. Fire	+	+	+	-	?	+	0	+
6. Recreation use	?(+)	+	?	-	+	+	+	+(?)
7. Conversion from trees or brush to grass	+	+(?)	+(?)	?	?	?	0	+
8. Conversion from grass to brush or trees	-	-	-	?	?	?	0	-
9. Urbanization	+	+	+	-	+	+	+	+

Expected responses: + = increase, - = a decrease, ? = questionable effect; and "0" indicates no effect expected.

Table 9

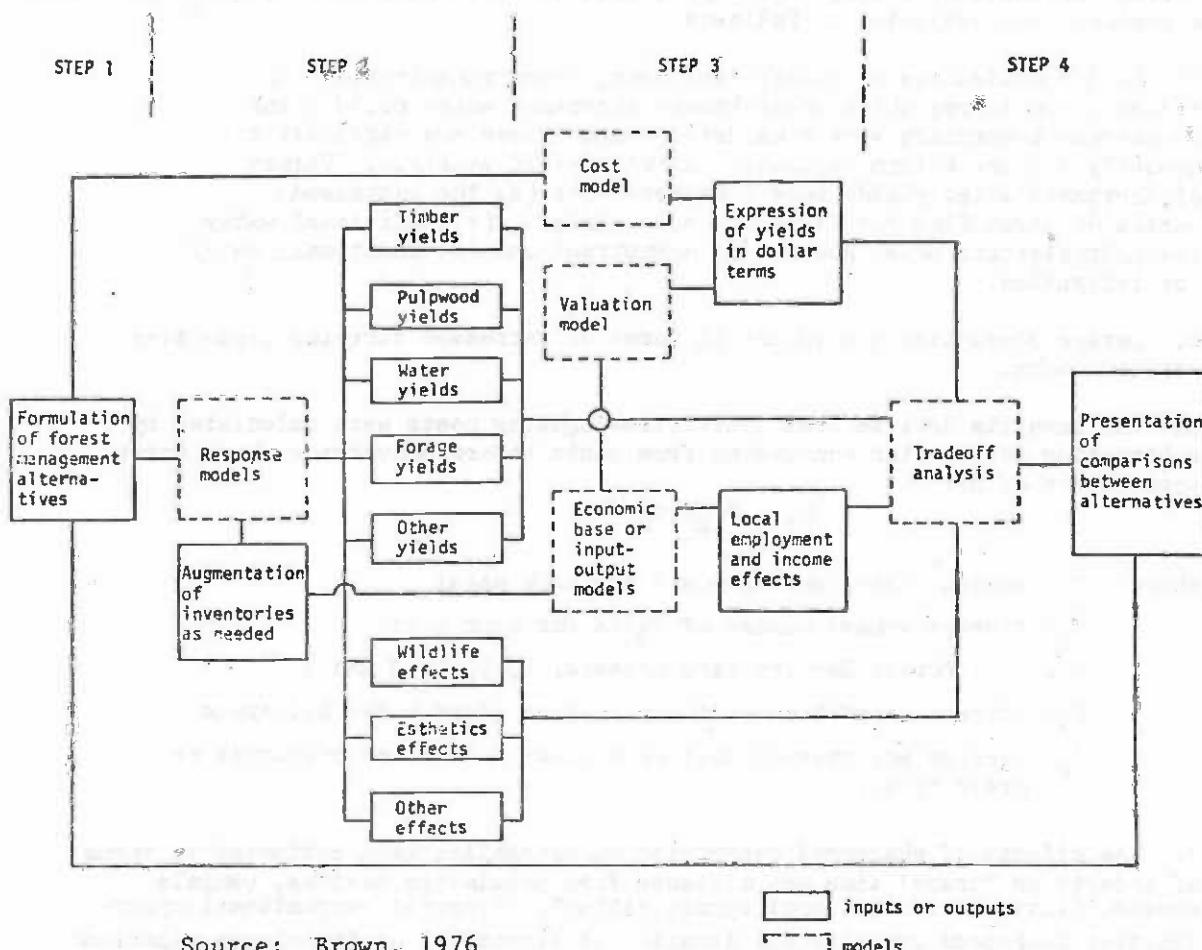
Relationships between water yield and timber yield for selected management alternatives.

<u>Management Alternative</u>	<u>Annual Yield Per Acre</u>	
	<u>Timber (\$)</u>	<u>Water (Acre-ft.)</u>
1. Harvest only, clearcut	3.5	0.20
2. Harvest only, shelterwood	3.7	0.18
3. Commercial thinning, clearcut	4.0	0.22
4. Commercial thinning, shelterwood	4.5	0.20
5. Pre-commercial thinning, clearcut	4.0	0.24
6. Pre-commercial thinning, shelterwood	4.5	0.22
7. Convert moist sites to grass and pre-commercial thinning, clearcut remaining timber...	3.5	0.40
8. Ibid, shelterwood	3.8	0.32

Source: Worley and Miller, 1969, as presented by Satterlund, 1972

Realistic evaluations of management alternatives for increasing water yield on wild-land watersheds should involve a multiple-product analysis far more complex than the preceding examples. Brown (1976) illustrated a procedure for analyzing multiple-product alternatives (Figure 3). As discussed by O'Connell (1971), to properly model the economics of management of multiple resources: (1) value and cost data should be determined by sound methodology, (2) local, regional and national impacts should be evaluated on the basis of income, employment, social and political criteria, (3) negative and positive effects on market and non-market outputs should be included, (4) marginal and incremental analysis should be used throughout, (5) a series of benefit-cost ratios should be determined for each alternative, and (6) "an economic optimum mix is obtained when the marginal rate of substitution is equal to the inverse ratio of the prices." A detailed economic analysis of the 8.4 million acre Salt-Verde watershed in central Arizona was conducted with the above factors in mind (Brown, O'Connell and Hibbert, 1974; O'Connell, 1974).

Figure 3. Alternative Analysis Procedure



Source: Brown, 1976

The purpose of the Salt-Verde study was to determine the economic feasibility of converting chaparral vegetation to grass in order to increase water yield and forage production for livestock, and to reduce the costs of fire-fighting (Brown, O'Connell and Hibbert, 1974). Costs of several methods of conversion were determined. Primary costs and benefits estimated over a 50-year period were expressed as present value (PV):

$$PV = \frac{Y_t}{(1+i)^t}$$

t=1 to 50

where: Y_t = cost or benefit in year t

i = discount rate (6 7/8 percent as recommended by U.S. Water Resources Council, 1973)

t = time in years

Present management was then contrasted to the various alternative impacts on water runoff, forage production, fires, recreation, soil losses, wildlife and esthetics. Each of these products was evaluated as follows:

a. In the estimation of runoff increases, evapotranspiration and transmission losses which occur before increased water could reach downstream reservoirs were considered (such losses are difficult to quantify and are seldom evaluated in water yield studies). Values of increased water yields were considered for (a) the increased period of streamflow for livestock and wildlife, (b) additional water for hydroelectric power generation downstream and (c) additional water for irrigation.

b. Forage production was valued in terms of increased carrying capacities for livestock.

c. The benefits derived from lower fire-fighting costs were calculated by subtracting costs after conversion from costs before conversion where costs were estimated by:

$$C_i = N_{ik} p_k c_k$$

where: C_i = annual fire-fighting costs for each area;

N_{ik} = average annual number of fires for each area;

k = U.S. Forest Service fire classes, A, B, C, D and E

p_k = average proportion of fires in size class k for all areas

c_k = average suppression cost of a class k fire for chaparral or grass fires.

d. The effects of chaparral conversion on recreation were estimated in terms of impacts on "travel time and distance from population centres, vehicle accessibility and recreational opportunities". Improved recreational opportunities increased quantity and duration of streamflow at downstream riparian recreation sites, increased access to ponderosa pine areas for foot traffic, and improved hiking and rock hunting conditions were estimated for conversion practices. The values of such benefits, however, were not presented.

e. Wildlife habitat was considered to be improved if conversion was limited to extremely dense stands, if no more than 50 percent of a stand was converted and if converted portions were in small openings spread throughout the stand. Again dollar values were not attached to such benefits.

f. The effects of different conversion methods and patterns were evaluated on esthetics but were not quantified.

Brown, O'Connell and Hibbert (1974) looked at conversion alternatives for 139 areas from both the benefit-cost ration (B/C) approach and the benefit-cost difference (B-C) which gives a measure of net benefits. Because of the recognized uncertainties in estimated changes in water yield, forage production, and incidence of wildfires, benefit cost analyses were performed using "...the lowest reasonable estimates of the above benefits." The results of their analysis are summarized in Table 10. Problems with such benefit-cost or net benefit analysis are encountered when dollar values cannot be attached to some of the benefits or costs.

Table 10

Average annual impacts (before conversion minus after conversion) for chaparral areas with B/C greater than one.

<u>Impacts</u>	Alternative I (best estimate)	Alternative I (low estimate)	Alternative II
<u>Value Determined impacts/acre</u>			
Water (acre-ft. off-site)	0.21	0.23	0.26
Forage (AUM)	0.22	0.06	0.24
Fire (\$)	0.34	0.09	0.40
<u>Economic effects (annuity)^{1/}</u>			
Gross Return (\$)	4.49	3.34	5.18
Cost (\$)	1.98	1.95	3.31
Net Return (\$)	2.51	1.39	1.87
<u>Non-Value Determined impacts (long term average impacts)</u>			
Recreation	some areas +, other no effect		
Soil	0 or + with proper mgt., negative with improper mgt.		
Wildlife habitat	+ with proper mgt., negative with improper mgt.		
Esthetics	+ or negative		

^{1/}
$$\text{Annuity} = \text{PV} \cdot i \cdot (1-i)^t / (1+i)^t - 1$$

Source: Brown, et. al., 1974

5. CONCLUSIONS AND RECOMMENDATIONS

The present paper presents an overview of some special problems associated with economic analyses of watershed projects. No attempt is made to provide systematic, detailed guidelines for project analysis, since these are covered in FAO's Economic Analysis of Forestry Projects (EAFF). The paper presents some examples and case studies of economic analyses of watershed projects and provides insights into how the analyst can consider watershed elements when they are imposed as constraints on projects that have other goals (e.g., wood production). The paper also surveys experience from the United States related to watershed project cost and benefit identification, valuation and comparisons.

A question remains: What lessons and conclusions can be drawn in terms of how the economist can work more effectively with hydrologists, foresters, agromists and other technical specialists in attempting to provide improved analyses of watershed projects? Based on the discussion in this paper and a review of a number of watershed project appraisals it would appear that following points are relevant in answering this question:

(1) In general, it would appear that the weakest link - or the major problem - in carrying out an appraisal of a watershed project relates to the identification and quantification of the physical input-output relationships and the costs and benefits involved. Once costs and benefits have been appropriately identified and quantified in physical terms, there do not appear to be any special problems involved in valuing them and comparing them in terms of the measures of project worth commonly used. With regard to this point, it would appear - as is indicated in a review of U.S. experience - that there are a lot more data available on input-output relationships than is generally thought and used in projects. The problem is that very little has been done to bring this information together in a practiced form that can be used by the general project planner. Thus there is a need to spend a lot more time and effort in developing comparative studies and translating highly technical information into practical guidelines that can be used by project planners.

We fully recognize that the technical specialist and researcher may argue that each case is a different one and that it is impossible to transfer the experience from one situation to another situation. While we agree that there is seldom a situation where experience from one project fits perfectly the conditions for another project, we also suggest that most analysts are dealing with averages and orders of magnitude in their attempts to analyze new projects, particularly in developing countries.

(2) Economists and the other technical specialists have to interact at all stages in the project planning process, for the economist cannot carry out an economic analysis unless he has the basic physical input-output information on which to base his analysis. The economist has to make known at an early stage his information needs. If he does not, then he can rightly be criticized. However if he has made his needs known and the appropriate information is not made available, then the primary responsibility for generating the needed information lies squarely on the shoulders of the hydrologist and other technical specialists. This is not within the economist's area of competence. His main responsibility starts when the appropriate information has been generated. We stress the word "appropriate" since in a number of cases it has been observed that a great deal of information has been accumulated for a project, but it is not the right information for the purposes of quantifying and valuing costs and benefits. Thus, for example, it is not enough to have information on average per ha. soil losses under various conditions. The agronomist and soil experts must make a specific link between soil loss and crop loss, for benefits in this case have to be specified in terms of consumption losses avoided. We do not "consume" soil,

we consume the products grown on it. In order to value such product losses avoided through implementation of a watershed project, we will need to link soil loss to crop production changes. The same argument holds for other types of relationships. Previous examples in this paper illustrated this point for several types of watershed projects.

With the above in mind, we strongly recommend that if an economic analysis is to be carried out for a watershed project then the economist should be included in the planning process at an early stage so he can make his information needs known. It may well be that the information he needs cannot readily be generated with available time and funds. In such cases, it will not be possible to carry out an economic analysis that considers both costs and benefits. Rather, the economist will have to stick to a cost-effectiveness analysis or some other types of partial analysis. Or, at the extreme, he will have to state that an economic analysis is not possible, given the present state of knowledge and data availability. However, at this point we should stress again that, in many cases, more information is available than is generally thought and used. It would be well worthwhile to spend some time and effort on bringing together such information in a readily understood and accessible fashion.

In the present paper we have attempted to review some of the technical and economic elements involved in watershed project planning. There are a number of detailed references which provide insights into specific aspects of watershed project planning, mainly from the technical point of view. These are cited in the paper and included in the list of references. A more thorough integration of the available technical information with the economist's approach to project analysis is needed.

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APPENDIX 1

WATERSHED MANAGEMENT OBJECTIVES RELEVANT FOR DIFFERENT CLIMATIC REGIONS

The following table presents a general view of the variety of watershed management objectives which may be relevant for different climatic regions. Obviously, there are exceptions to such a generalized ranking. But it does indicate some general considerations. Specific site characteristics and other factors such as proximity to population centers and level of economic development may in some situations reorder the watershed management priorities listed. For example in a "mid-latitude mixed forest with abundant rainfall and water supplies, the management of municipal watersheds for maintaining or perhaps increasing the quantity of water yield to satisfy the demands of an increasing population may be a major objective. Conversely, the goal of increasing the quantity of water in many desert ecosystems may be unrealistic from a watershed management viewpoint because of the lack of opportunities to do so.

SUGGESTED IMPORTANCE OF WATERSHED MANAGEMENT OBJECTIVES FOR DIFFERENT CLIMATE - VEGETATION REGIMES OF THE WORLD.

Climate ^{1/}	Typical Annual Precipitation (cm)	Comments	Increase Quantity	WATERSHED MANAGEMENT OBJECTIVES 2/				
				Reduce Flooding	Drainage of Wetlands	Minimize Erosion & Sedimentation	Improve Water Quality	Minimize Wind Erosion
Boreal Forest	25 to 75	6 months below freezing	3	2	1	3	2	4
Mid-Latitude Mixed Forest	50 to 200	hot summers cold winters	2	2	3	1	2	4
Mid-Latitude Coastal Evergreen Forest	40 to 500	mild, humid high winter precip.	3	2	4	1	2	4
Mediterranean Scrub Woodland	40 to 90	warm, dry summers wet winters	1	2	4	2	3	3
Mid-Latitude Steppe	25 to 85	wet, hot summers cold winters	3	2	4	1	2	2
Desert	0 to 25	evapotranspiration exceeds precip.	2 3/	2	4	2	3	2
Tropical Rain and Semi-deciduous Forests	165 to 760	rainfall evenly distributed, warm, wet	4	2	3	1	3	4
Tropical Savanna and Thorn Scrub Woodland	75 to 130	pronounced wet and dry periods	2	2	4	1	2	3
Mountain								
- Precipitation limiting in adjacent areas	variable	generally an increase in precip.	1	2	4	2	2	4
- Precipitation abundant	variable	with elevation	3	2	4	1	2	4

^{1/} As classified by Rummey (1968); Polar ice cap and tundra climates were not considered in this analysis.

^{2/} Objectives: 1=Primary; 2=Secondary; 3=Usually not of major importance; 4=Little or no importance. It should be noted that such objectives are highly dependent upon individual watershed characteristics including topography, slopes and soils and other factors such as land use, population and level of economic development.

^{3/} Although the goal of increasing water supplies in desert areas is of top priority, watershed management opportunities for increasing water yield and extremely limited and, therefore, not considered a primary objective of management.

DISCOUNTING PROCEDURES FOR PROJECT APPRAISALS:

Common Problems and Appropriate Solutions

by

Thomas W. Houghtaling and Hans M. Gregersen *y*

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Definitions

ROR - Internal Rate of Return (general)

ERR - Economic Internal Rate of Return

FIRR - Financial Internal Rate of Return

NPW - Net Present Worth

PV - Present Value

1. INTRODUCTION

Forestry projects nearly always involve a number of years between the time when the first project investment is made and when final outputs (benefits) from the project occur. Usual practice in appraising such projects is to calculate some measure(s) of project worth that take time into account. The most common measures calculated include the net present worth (NPW) and the internal rate of return (ROR). Both these measures are discussed in Chapter 9 of *Economic Analysis of Forestry Projects*^{1/}, in terms of both financial and economic analyses.

The purpose of the present paper is to explore in more technical detail solutions to some common problems encountered in using discounting and compounding formulas and procedures.

Specifically, the following three questions are dealt with in some detail:

- (i) How should years or time intervals be defined and designated in project analyses? What mistakes commonly occur when years (time intervals) are improperly defined, and how can the common errors be avoided?
- (ii) How should inflation be treated and how can we best treat situations where both growth rates and discount rates have to be treated simultaneously (e.g., real prices for timber may be increasing at 3 percent per year and we are using a 10 percent discount rate to calculate present values for a particular investment analysis)?
- (iii) Finally, we touch on the question of the importance of uncertainty concerning future values (costs, prices, physical magnitudes) depending on a) the period to which the uncertainty refers and b) the discount rate used for present value calculations, or the estimated internal rate of return of the project.

2. PROPER DESIGNATION AND TREATMENT OF TIME INTERVALS

Conventional investment analysis is carried out on an annual basis, with rates of return expressed in percent per annum on a compound basis. Costs and benefits which occur at any time during a given year are presumed to occur at a single point in time, conventionally, at the beginning of the year. A year can be defined to begin on any date, i.e., January 1, April 1, June 15, etc. Often in forestry a "year" begins on the day of planting or some other initial investment activity. It is only by convention that a period of one year generally is chosen as the time interval for investment analysis. It would be equally valid (and perhaps slightly more accurate) to choose a shorter period, such as one quarter or one month. However, it is unlikely that the added complexity would be justified, except perhaps for short-term projects at extremely high discount rates. Cash flow tables normally also are constructed on an annual basis, as is illustrated by Table 1, for a one hectare fuelwood plantation in Korea.^{2/}

^{1/} FAO Forestry Paper No.17, FAO, Rome, 1979, hereafter referred to as EAFF.

^{2/} See Case Study No. 2, in *Economic Analysis of Forestry Projects: Case Studies*. FAO Forestry Paper No. 17, Supp. 1, FAO, Rome, 1979.

Table 1 - Korea Fuelwood Cash Flow Analysis

2.1 Designating Years in Project Analysis

There is no single convention regarding the designation of year numbers in investment analysis. Consequently, some confusion arises in practice, which often leads to errors in analysis. In the case of forest plantation projects, the age of the stand of trees (the number of years since planting) has often been used as the basis for numbering years when planting occurs in the initial investment year. Thus, the initial investment year would be labeled "zero". In such cases the cash flow table year designation and the age of the plantation would coincide. Often site preparation or other costs attributable to a new plantation occur one or more years before planting. Thus, using year designations corresponding to the age of the plantation would involve the use of negative years (for investment costs occurring one or more years before planting). While such designation would not affect the results of the analysis, it could lead to unnecessary confusion among persons reviewing the work. The convention recommended here is to designate years according to the age of the initial investment outlay for the project, with year "zero" as the "first" year of the investment project. In general terms, "year n" is the $(n+1)$ th year in any analysis.

In many cases the project analyst does not "write up" the appraisal report. Instead, another person "back in the office" is assigned the task. Therefore, confusion over the designation of years is often not exclusively confined to those who read the appraisal report, but rather it surfaces within the appraisal report due to inconsistency in the designation of years by two or more individuals who work on the appraisal.

In the Korea fuelwood project (Table 1) the beginning of year zero corresponds to the date of planting, since no investments took place prior to the year of planting. Therefore, the age of trees removed at final harvest is 20.

The calculation of the net present worth (NPW) of a project is made easier by designating the first year of the investment (project) as year zero. Since NPW is normally expressed in terms of the first year (the "present" in terms of the project decision), the year number automatically corresponds to the number of years for which the net benefits (costs) need to be discounted. Each net benefit (cost) in Table 1 can be multiplied by the discount factor, $\frac{1}{(1+i)^n}$, where (i) equals the annual interest (discount) rate and (n) equals the year number shown in the column heading) to obtain the present value for each net benefit (cost) entry. The NPW of the Korea project (the sum of each year's net present value) at a 10 percent discount rate equals W170.0 thousand. ^y

2.2 Treating Equal Annual or Periodic Costs and Benefits

When a net benefit (cost) occurs annually or on a regular periodic basis for a sequence of years, the use of formulas to calculate the present value of such benefits or costs greatly simplifies the determination of the NPW, since the number of calculations is reduced. Table 2 summarizes the formulas needed to calculate the present and future values of annual and periodic "payments". ^{2/} The formulas in Table 2 are labeled based on the

^y See EAFP, Chapter 9, for further discussion of NPW calculations.

^{2/} By convention these formulas are titled "payment" formulas. The word "payment" describes a sequence of two or more equal costs or benefits which occur annually or periodically.

assumption that interest rates are expressed and compounded on an annual basis. An amount of time other than one year could be used. The periodic formulas assume that two or more years (or other specified equal lengths of time) separate payments. The derivations of the formulas in Table 2 are presented in Appendix 1. The application of the present value formulas is illustrated below, using the Korea example.

2.3 "End of Year" vs. "Beginning of Year" Designations

"End of year" designations imply that annual payments start one year from the present and that periodic payments start one period from the present. This is equivalent to saying that annual (periodic) payments start at the beginning of the second year (period).

"Beginning of year" designations imply that annual (periodic) payments begin immediately and at the beginning of each successive year (period).

In both cases, in terms of discounting or compounding, the beginning of one year (period) is considered equivalent to the end of the previous year (period).

The only significance of distinguishing between "end" and "beginning" of year payments relates to the first year (period) of an annual (periodic) series of payments. More specifically, it is only of concern when the analyst uses one of the formulas for present value of an annual (periodic) series of payments. However, use of these formulas is common in forestry projects (e.g., calculating soil expectation values, present value of annual taxes, protection costs, etc.) so the difference is worth noting and is explained in more detail below. *y*

Quite often one encounters investment analyses where the first year is labeled "year 1" and the values (net benefits or costs) for that year are discounted back one year to arrive at NPW. The implicit assumption in such cases is that the analyst is using an "end of year" approach, i.e., assuming that any payment in a given year occurs at the end of that year. As explained above, we prefer to use the beginning of year assumption in assigning costs and benefits. Thus, we label the first year as "0" and do not discount the net benefit or cost value occurring during that year. Either approach can be used and will provide correct results, so long as the assumption is appropriately stated. It is a simple matter to adjust from one to the other.

y A common mistake in forestry is to estimate an annual land rental equivalent (A) of a given land value (V) by applying the formula $A = V(i)$ where i equals the discount rate. In this case the assumption underlying the formula is that rental payments start one year from the present (i.e., end of first year or beginning of second year). In reality, rental payments would start at the beginning of the first year, and the appropriate formula would be $A = V(i)/(1+i)$. Other common mistakes have been identified. Appropriate treatment of annual and periodic series are discussed in the following paragraphs.

Table 2 - Annual and Periodic Payment Formulas

	Payments Begin One Year (or Period) From Present		Payments Begin Immediately	
	Finite Number of Payments	Infinite Number of Payments	Finite Number of Payments	Infinite Number of Payments
1. DISCOUNTED ANNUAL PAYMENT FACTOR	$\frac{(1+i)^n - 1}{i(1+i)^n}$	$\frac{1}{\frac{i}{1+i}}$ (2)	$1 + \frac{(1+i)^n - 1}{i(1+i)^n}$ (3) or $\frac{(1+i)^{n+1} - 1}{i(1+i)^n}$	$1 + \frac{1}{i}$ (4) or $\frac{1+i}{i}$
2. COMPOUNDED ANNUAL PAYMENT FACTOR	$\frac{(1+i)^n - 1}{i}$	n.a.	$(1+i)^n + \frac{(1+i)^n - 1}{i}$ or $\frac{(1+i)^{n+1} - 1}{i}$	n.a.
3. ANNUAL CAPITAL RECOVERY FACTOR	$\frac{1(1+i)^n}{(1+i)^n - 1}$	n.a.	n.a.	n.a.
4. ANNUAL SINKING FUND FACTOR	$\frac{1}{(1+i)^n - 1}$	n.a.	n.a.	n.a.
5. DISCOUNTED PERIODIC PAYMENT FACTOR	$\frac{(1+i)^{nt} - 1}{(1+i)^n [(1+i)^t - 1]}$	$\frac{1}{(1+i)^t - 1}$	$\frac{(1+i)^{(n+1)t} - 1}{(1+i)^n [(1+i)^t - 1]}$	$\frac{(1+i)^t}{(1+i)^t - 1}$
6. COMPOUNDED PERIODIC PAYMENT FACTOR	$\frac{(1+i)^{nt} - 1}{(1+i)^t - 1}$	n.a.	$\frac{(1+i)^{(n+1)t} - 1}{(1+i)^t - 1}$	n.a.

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i = rate of interest (discount) in decimal form
n = number of years or periods until last payment
t = number of years between periodic payments

2.4 Using "End of Year" Annual Payment Formulas

The NPW for the Korea project cash flow (Table 1) as derived above was obtained by discounting each year's net benefit (cost). A much easier method is to apply the finite discounted annual payment factor for a payment beginning in one year (row 1, column 1 of Table 2) to the year 1-2 net costs and the year 7-19 net benefits. These discounted values are expressed in terms of the year prior to the start of the net benefits (costs), i.e., years 0 and 6, respectively. The discounted value of net benefits for years 7-19 must be further discounted for 6 years to arrive at present value. The other 6 individual net benefits (costs) are discounted individually as before. Calculations are shown in Table 3. Step by step explanations of the procedures used in Table 3 are presented in Appendix 5.

2.5 Using "Beginning of Year" Annual Payment Formulas

Another equally valid way to calculate the above NPW would be to use the finite discounted annual payment factor for a "beginning of year" payment (row 1, column 3 of Table 3) for the same two sequences of annual payments. This method is shown in Table 4. Only columns 3 and 4 have changed from Table 3. The discounted values shown in column 4 of Table 4 are expressed in terms of the year in which the payments begin, not in terms of one year before the payments begin, as was the case in Table 3. Each method (Table 3 or Table 4) gives the same NPW, and it does not matter which method is used. However, it is obviously necessary to distinguish between the two methods. One of the common errors in financial or economic analysis of forestry projects is the failure to make such a distinction, which often leads to the use of the wrong number of years for discounting.

The distinction between the two designations can be put in another way. When using "end of year" designations, the present value of a series of annual payments starting in year $n+1$ will be expressed in terms of present value in year n . When using "beginning of year" designations, the present value of a series of annual payments starting in year $n+1$ will be expressed in terms of present value in year $n+1$.

2.6 Using "Periodic" Payment Formulas

To illustrate the use of periodic payment formulas, another example can be used. The cash flow is presented as Table 5. Two sets of periodic net payments occur. Net benefits of 90.2 occur seven times from year 6 through year 18 at regular intervals of two years, and net costs of 2.4 occur nine times from year 3 through year 19, also at intervals of two years. ^{1/} As in the case of annual payments, periodic payments can be defined as beginning in one period after the base year of discount, or as beginning immediately. The method of calculating NPW assuming payments beginning "next" period ("end of period" payments) is illustrated in Table 6 using the formula from row 5, column 1 of Table 2. ^{2/} The other equally correct method is to use the discounted periodic payment factor for a payment beginning immediately ("beginning of period" payments). This method of calculating NPW, using the formula from row 5, column 3 of Table 2, is shown in Table 7.

^{1/} To be consistent with the annual cost treatment in the Korea cash flow above, net costs for years 1-2 are treated as annual costs, and net costs for alternate years between 3-19 are treated as periodic costs.

^{2/} The procedures used in Table 6 are similar to the procedures used in Table 3, which are more fully described in Appendix 4.

Tables 3 and 4 - Two Methods of Calculating Net Present Worth (NPW) for Korea Fuelwood Project

Table 3

Discounted Value of Annual Payment Expressed
in Terms of the Year Prior to the First Payment

(i=10%)				
Year	Net Benefit or (cost)	Discounted Value of Annual Payment		Present Worth (Year 0)
		Year	Value	
[1]	0	(139.9)		(139.900)
[2]	1-2	(2.4)	0	(4.165)
[3]	3	2.2		1.653
[4]	4	6.9		4.713
[5]	5	16.1		9.997
[6]	6	34.6		19.531
[7]	7-19	43.9	6 311.837 ^{1/}	76.024
[8]	20	687.5		102.192

Net Present Worth (NPW) = 170.0

Table 4

Discounted Value of Annual Payment Expressed
in Terms of the Year in Which Payment Begins

(i=10%)				
Year	Net Benefit or (cost)	Discounted Value of Annual Payment		Present Worth (Year 0)
		Year	Value	
[1]	0	(139.9)		(139.900)
[2]	1-2	(2.4)	1 4.582	(4.165)
[3]	3	2.2		1.653
[4]	4	6.9		4.713
[5]	5	16.1		9.997
[6]	6	34.6		19.531
[7]	7-19	43.9	7 343.021	176.024
[8]	20	687.5		102.192

Net Present Worth (NPW) = 170.0

^{1/} This value of 311.837 can be added to the year 6 net benefit of 34.6. The result (346.437) can then be discounted 6 years to get 195.555. This method will save one calculation.

Table 5 - Mythopia Cash Flow Analysis

	YEAR																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
[1] BENEFITS (fuelwood)					32.5		130.0		130.0		130.0		130.0		130.0		130.0		130.0		1625.0
[2] COSTS																					
[3] Establishment	130.0																				
[4] Supervision	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	
[5] Misc. (tools, etc.)	7.5																				
[6] Harvesting					9.4		37.4		37.4		37.4		37.4		37.4		37.4		37.4		937.5
[7] Total Cost	139.9	2.4	2.4	2.4	11.8	2.4	39.8	2.4	39.8	2.4	39.8	2.4	39.8	2.4	39.8	2.4	39.8	2.4	39.8	2.4	937.5
[8] NET BENEFIT (cost)	(139.9)	(2.4)	(2.4)	(2.4)	20.7	(2.4)	90.2	(2.4)	90.2	(2.4)	90.2	(2.4)	90.2	(2.4)	90.2	(2.4)	90.2	(2.4)	90.2	(2.4)	687.5

Tables 6 and 7 - Two Methods of Calculating Net Present Worth (NPW) for Mythopia Project

Table 6

Discounted Value of Annual/Periodic Payment
Expressed in Terms of Year Prior to First Pay.

(i=10%)

Year ^{1/}	Net Benefit or (cost)	Discounted Value of Annual/Periodic Pay.		Present Worth (Year 0)	
		Year	Value		
[1]		[2]	[3]	[4]	[5]
[1]	0	(139.9)		(139.900)	
[2]	1-2	(2.4)	0	(4.165)	(4.165)
[3]	3-19 (p)	(2.4)		(9.373)	(8.521)
[4]	4	20.7		14.138	
[5]	6-18 (p)	90.2	4.	316.417	216.117
[6]	20	687.5		102.192	

Net Present worth (NPW) = 180.761^{2/}

Table 7

Discounted Value of Annual/Periodic Payment
Expressed in Terms of Year in Which Pay. Begins

(i=10%)

Year ^{1/}	Net Benefit or (cost)	Discounted Value of Annual/Periodic Pay.		Present Worth (Year 0)	
		Year	Value		
[1]	0	(139.9)		(139.900)	
[2]	1-2	(2.4)	1	(4.582)	(4.165)
[3]	3-19 (p)	(2.4)	3	(11.341)	(8.521)
[4]	4	20.7		14.138	
[5]	6-18 (p)	90.2		382.864	216.117
[6]	20	687.5		102.192	

Net Present Worth (NPW) = 180.761

^{1/} The letter "p" following a group of years refers to a periodic payment occurring every two years.

^{2/} The NPV under this harvest assumption is greater than under the original assumption due to earlier harvesting.

2.7 Expressing Benefits and Costs in Annual Terms

For some projects it is useful to express a single payment as an equivalent sequence of annual payments at some specified discount rate, e.g., an investment cost which is annualized over the life of the investment. For example, in many forest industry projects output is relatively constant for a sequence of years. To determine whether the project is justified, annual benefits can be compared with annual costs (including annualized fixed costs). Also, for such industrial projects it is useful to know in any given year what the average cost of production is (including interest on and depreciation of fixed assets).

Multiple payments can also be expressed in annual terms. For example, if harvest benefits occurred in years 15, 25, and 30, they could be expressed in annual terms over the entire rotation. To do so, one must first calculate the present value of these harvest benefits, and then "annualize" that single value, applying the same discount rate used to calculate the present value. Another example of annualizing a group of costs and benefits is illustrated by the calculation of soil rent. First, the soil expectation value (the NPW of a project over an infinite period, excluding land cost) is calculated, and then soil rent is defined as the annual equivalent of the soil expectation value.

Very often the annual capital recovery factor is used to determine the amount of equal installments (beginning in one year) necessary to repay a loan granted "today". (See "Treatment of loans", below). In the case of a loan it makes no sense to begin repaying the loan immediately since it would serve only to reduce the amount of the loan granted. The convention of using this annual capital recovery factor (which assumes payments to begin in one year) applies also to cases where single payments of equity capital are annualized (see Appendix 1, page 3, footnote 1).

The conventional method of annualizing a payment is to use the annual capital recovery factor (row 3, column 1 of Table 2). By multiplying the single payment by this factor, the "equivalent" sequence of annual "end of year" payments is determined. For example, in the Korea cash flow table (Table 1) it is evident that the "establishment" and "miscellaneous" costs of W137.5 all occur in year zero. At a 10 percent discount rate this single cost is equivalent to an annual cost (years 1-20) of W6.2, using the annual capital recovery factor.

2.8 Treatment of Loans

Often a financial investment analysis will include a loan. In a financial cash flow table, the loan amounts received are treated as receipts and the loan amounts plus interest repaid are treated as disbursements. The loan is treated exactly like any other receipt or disbursement. In many cases, the exact loan schedule is not detailed in the information given the analyst. Instead, the loan disbursement schedule is given together with the loan rate of interest, then the repayment schedule is defined only by the number of years of no repayments (grace period), if any, the number of years of repayment of interest (sometimes in precalculated amounts), and the number of equal installments of repayment of capital and interest in the final years of the loan. The analyst must then make a detailed schedule from the information given.⁷ When making a loan schedule, the analyst needs to define carefully the year numbers. Otherwise, it is likely that the loan schedule will contain errors. (This is a common source of error in the projects reviewed.)

⁷ Often the "grace period" of a loan refers to the number of years during which no principal is repaid (interest may or may not be repaid during this "grace" period).

A case study of Philippine smallholder forestry provides an example of a loan disbursement and repayment schedule, including a grace period on repayment. Table 8 reproduces the cash flow schedule from this project for an individual smallholder who receives a loan of 1 500 pesos for each of the first four years of the project.^{1/} Line 1 in Table 8 shows the loan as a receipt by the smallholder. He has a three year grace period beyond year 3 before he starts repaying interest and principal. Then he pays off the interest on the first 7 years during the 8th and 9th years of the project and finally repays the remaining balance (principal plus current interest) in 6 equal installments (calculated using the capital recovery factor, described above) during the 10th to the 15th years.

Table 9 shows the calculations necessary to determine the schedule of repayments, considering the grace period and using a 12 percent interest rate. When there is no grace period, one can merely use the capital recovery formula shown in Table 9 to determine the appropriate equal annual repayments.

A useful method to check on the accuracy of the loan schedule is to calculate the loan's "internal rate of return" (ROR). ^{2/} The ROR for the loan must equal the loan rate of interest if the schedule was done correctly. Alternatively, the NPW of the loan can be calculated using the loan rate of interest as the discount rate. The NPW must then equal zero. Such a check will detect most computational errors and most errors in timing. However, if timing of the entire schedule is incorrect, (but the timing and calculating within the schedule are correct) this check will not detect the error. Therefore, it is necessary to make sure that the actual loan starting date, ending date and the numbers of disbursements and repayments are correct.

3. DEVELOPMENT OF COMPOSITE DISCOUNT RATES

Most investment analyses are conducted using real values rather than current (nominal) values, which include general price inflation. Discount rates used and internal rates of return calculated are real rates. Rates of return on alternative investments, such as bank accounts and bonds, are commonly given in current terms (they include effects of general price inflation) and therefore, are not directly comparable with real rates of return calculated for projects or alternative investments.^{3/} The rate of discount (*i*) used in the compound and discount formulas (Table 2) can be defined as either a current rate (*v*) or a real rate (*r*). The formulas in these tables are used in the same manner regardless of the assumption made. However, it is important to ensure that if a current rate is chosen all values entered into the cash flow are current values, and if a real rate is chosen, all cash flow values are real values.

^{1/} Case Study No. 1 in FAO Forestry Paper No. 17, Supp. 1

^{2/} The loan's ROR is calculated by equating the present value of loan disbursements with the present value of loan receipts. At one discount rate (the loan's ROR) such an equality will hold.

^{3/} Increasing general price inflation reduces the real rate of return earned/paid on "fixed yield" investments (i.e., loans, bank accounts, bonds, etc.). The real rate of return on such investments varies inversely to the rate of inflation. See H. Gregersen, "Effect of Inflation on Evaluation of Forestry Investments." Journal of Forestry, Vol. 73, No. 9, pp. 570-572, 1975.

TABLE 8 Financial Cash Flow, 10 ha. Plantation

Philippine Smallholder Plantation Project
(value in constant pesos)

	YEARS																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Cash Receipts																				
1. Bank loans	1500	1500	1500	1500	-	-	-	5523	6174	6174	6810	6810	7434	7434	8046	5174	6174	6174	6174	
2. Sales	-	-	-	-	-	-	-	5523	6174	6174	6810	6810	7434	7434	8046	6174	6174	6174	6174	
Total	1500	1500	1500	1500	-	-	-	5523	6174	6174	6810	6810	7434	7434	8046	5174	6174	6174	6174	
Cash Disbursements																				
3. Land preparation	590	590	590	590	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
4. Purchase seedlings	130	130	130	130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
5. Lining/Dig/Plant	300	300	300	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
6. Replanting	130	130	130	130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
7. Fertilizing	300	300	300	300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
8. Weeding	550	550	550	550	-	-	-	275	275	275	275	275	275	275	275	275	275	275	275	
9. Singling	-	-	-	-	-	-	-	-	100	100	100	100	100	100	100	100	100	100	100	
10. Crops/Livestock	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	2000	2000	2000	2000	-	-	-	275	375											
Loan Payments																				
11. Accum. interest	-	-	-	-	-	-	-	3200	3050	-	-	-	-	-	-	-	-	-	-	
12. Princ. & interest	-	-	-	-	-	-	-	-	-	1459	1459	1459	1459	1459	1459	1459	-	-	-	
Total	-	-	-	-	-	-	-	3200	3050	1459	-	-	-							
Cash Balance After Loan Payments	(500)	(500)	(500)	(500)	-	-	-	2048	2749	4340	4976	4976	5600	5600	6212	5799	5799	5799	5799	

Table 9

Derivation of Farmer Loan Repayments

Year	Loan Amount 1/	Interest Due At End of Year 7 (Beginning of year 8)
0	P 1,500	P 1816
1	P 1,500	P 1461
2	P 1,500	P 1143
3	P 1,500	P 860
Total		P 5280

The annual repayments of the loan for years 9 - 14 (line 11, Table 5) are derived as follows:

$$A = P \frac{.12(1.12)^6}{(1.12)^6 - 1}$$

$$= P 6,000 (0.2432) = P 1459$$

The factor in parentheses is called the "capital recovery multiplier", and is given as follows:

$$\frac{i(1+i)^n}{(1+i)^n - 1}$$

The value of this multiplier can be found in most tables of compound and discount factors.

- 1/ Assuming 2 ha planted per year at a total annual cost equal to P 2000 (Table 2) 75 percent of this amount, or P 1500, is covered by the Bank loan.
- 2/ Arbitrarily set at this level in order to keep interest payments in years 7 and 8 approximately equal.
- 3/ P 2080 plus P 970.

3.1 Using Current (Nominal) Values (i.e., Including Inflation)

When a project is being implemented, what is actually paid for inputs and received for outputs is in current price terms. Therefore, general price inflation must somehow be considered in the appraisal in order to determine the actual cash flow. Thus, whether or not the project analysis is carried out on a current or real value basis, current values must be taken into account for budgeting purposes. When the analysis is expressed in current value terms, each entry in the cash flow table can be used directly for budgeting purposes. However, it is a simple matter to adjust a real value cash flow to a current value cash flow and vice versa.

To convert real values and real discount rates to current terms, it is first necessary to estimate a general rate of price inflation for the project years. Since individual projects are usually too small to significantly affect the level of general price inflation, the expected inflation rate can be estimated independently of the project.^{1/} The current values of inputs and outputs for any given year (y) can then be determined by multiplying the real values by $(1+f)^y$, with f equal to the estimated average annual inflation rate.^{2/}

If one wishes to combine the real value discount rate (r) with the inflation rate (f), then one can calculate a current value discount rate (v) as being equal to:
 $((1+r)(1+f)-1)$ This rate, v, would be used if prices were expressed in current value terms.

3.2 Using Real Values (i.e., Net of Inflation)

It is generally much easier to define (i) (the discount rate to be used) as a real rate (r) and also express each cost and benefit in real terms. The numbers entered into the cash flow table will be more easily determined, since no inflation factors need to be estimated. This eliminates a major potential source of error in cash flow tables; it makes expected real price increases more clearly visible, and the use of annual and periodic payment formulas will be greatly simplified. Also, real values in the cash flow table will probably be more meaningful to the decision-maker. Because of these reasons, it is recommended here that analyses be carried out in real value terms. Once the "real" cash flow is determined, the appropriate contingencies for inflation can be determined and allocated for budgetary purposes.

^{1/} Over the long term, however, rates of inflation are difficult to estimate and are subject to a high degree of error. The analyst must recognize the limitation on the estimated rate(s). Also, the rates of inflation often vary between the domestic economy and the offshore (exporting) countries, which means that two or more rates of inflation must be estimated.

^{2/} The value (f) is an average rate of inflation. If the rate of inflation is expected to vary from year to year, it would be more accurate to discount each yearly value by dividing by:

$$(1+r)^y((1+f_0) \times (1+f_1) \times (1+f_2) \times \dots \times (1+f_{y-1}))$$

where (f_0) equals the rate of inflation during year 0, (f_1) equals the rate of inflation during year 1, etc., and (y) equals the given year.

Whether current or real values are used, the analyst needs to establish a frame of reference for comparisons. A real value frame of reference is preferable, since it is easier to comprehend. ^{1/}

In summary, the analyst can use either real or current values in his analysis. The results of the analysis will be the same, so long as he consistently uses the same basis throughout the analysis. For the reasons given above, we recommend working with real values. The results can be converted easily to current value terms.

3.3 Introducing "Real" Value Rates of Growth or Decline

Many prices of inputs and outputs will not remain at their year zero levels, even in real terms. If real price increases are expected, e.g., for stumpage prices, then each real price observed in year zero must be multiplied by $(1+g_p)^n$, where (g_p) equals the estimated average annual growth rate in the price and (n) equals the number of years since year zero. If real prices are expected to decline, then (g_p) would be negative. Usually expected price growth rates are expressed in average annual terms, even though rates actually fluctuate from year to year. It is very seldom that such fluctuations can be predicted in advance. Therefore, only expected annual averages of (g_p) are used.

Sometimes constant relative quantity changes are expected to occur. The real value of a cost or benefit in year (n) would be $(a(1+g_p)^n(1+g_q)^n)$, where (a) equals the present price times quantity of the input or output, (g_p) and (n) are defined as above, and (g_q) equals the average annual quantity growth rate. In such cases a composite growth rate (g) can be defined which equals $((1+g_p)(1+g_q)-1)$. This composite (g) is simpler to use. ^{2/} All further references to the real growth rate, (g) , unless otherwise stated, refer to this type of composite rate. If (g) has only one component, say (g_p) , the other component (g_q) 's can be defined as being equal to zero. In that sense, (g) is always a composite of component (g) 's.

The compounded and discounted annual and periodic payment formulas shown in Table 2 can be restated under the assumption that composite growth rates exist. Table 10 lists these revised formulas. The derivation of the formulas is presented in Appendix 2. The first four rows of Table 10 are relevant when the discount rate (i) is greater than the growth rate (g) . In that event, a composite discount rate (d) equals $\frac{(1+i)}{(1+g)} - 1$. In other words, the overall effect of compounding at a rate (g) and discounting at a rate (i) (where $i > g$) is a discount effect equal to a rate (d) . The bottom four rows of Table 10 restate the factors listed in the top four rows for the case where the discount rate (i) is less than the growth rate (g) . In that event, a composite compound rate (c) equals $\frac{(1+g)}{(1+i)} - 1$.

^{1/} It is sometimes argued that current rates of interest, such as rates on savings accounts or government bonds, should be used as frames of reference (i.e., as alternative rates of return). This may be true in the short term, when the inflation rate is likely to remain unchanged. However, for long term projects such as in forestry, this will likely lead to confusion and may result in poor decisions.

^{2/} A composite (g) can be composed of any number of separate component (g) 's.

Table 10 - Annual and Periodic Payment Formulas, Assuming the Payments Increase at an Annual Rate (g)

	Payments Begin One Year (or Period) From Present		Payments Begin Immediately	
	Finite Number of Payments (1)	Infinite Number of Payments (2)	Finite Number of Payments (3)	Infinite Number of Payments (4)
1. DISCOUNTED ANNUAL PAYMENT FACTOR (d_g)	$\left[\frac{(1+d)^n - 1}{d(1+d)^n (1+g)} \right]$	$\left[\frac{1}{d(1+g)} \right]$	$\left[\frac{(1+d)^{n+1} - 1}{d(1+d)^n} \right]$	$\left[\frac{1+d}{d} \right]$
2. COMPOUNDED ANNUAL PAYMENT FACTOR (i_g)	$\left[\frac{(1+g)^{n-1} [(1+d)^n - 1]}{d} \right]$	n.a.	$\left[\frac{(1+g)^n [(1+d)^{n+1} - 1]}{d} \right]$	n.a.
3. DISCOUNTED PERIODIC PAYMENT FACTOR (d_g)	$\left[\frac{(1+d)^{nt} - 1}{(1+g)^t (1+d)^{nt} [(1+d)^t - 1]} \right]$	$\left[\frac{1}{(1+g)^t [(1+d)^t - 1]} \right]$	$\left[\frac{(1+d)^{(n+1)t} - 1}{(1+d)^{nt} [(1+d)^t - 1]} \right]$	$\left[\frac{(1+d)^t}{(1+d)^t - 1} \right]$
4. COMPOUNDED PERIODIC PAYMENT FACTOR (i_g)	$\left[\frac{(1+g)^{(n-1)t} [(1+d)^{nt} - 1]}{(1+d)^t - 1} \right]$	n.a.	$\left[\frac{(1+g)^{nt} [(1+d)^{(n+1)t} - 1]}{(1+d)^t - 1} \right]$	n.a.
5. DISCOUNTED ANNUAL PAYMENT FACTOR (i_c)	$\left[\frac{(1+c)^n - 1}{c(1+i)} \right]$	n.a.	$\left[\frac{(1+c)^{n+1} - 1}{c} \right]$	n.a.
6. COMPOUNDED ANNUAL PAYMENT FACTOR (i_c)	$\left[\frac{(1+i)^{n-1} [(1+c)^n - 1]}{c} \right]$	n.a.	$\left[\frac{(1+i)^n [(1+c)^{n+1} - 1]}{c} \right]$	n.a.
7. DISCOUNTED PERIODIC PAYMENT FACTOR (i_c)	$\left[\frac{(1+c)^{nt} - 1}{(1+i)^t [(1+c)^t - 1]} \right]$	n.a.	$\left[\frac{(1+c)^{(n+1)t} - 1}{(1+c)^t - 1} \right]$	n.a.
8. COMPOUNDED PERIODIC PAYMENT FACTOR (i_c)	$\left[\frac{(1+i)^{(n-1)t} [(1+c)^{nt} - 1]}{(1+c)^t - 1} \right]$	n.a.	$\left[\frac{(1+i)^{nt} [(1+c)^{(n+1)t} - 1]}{(1+c)^t - 1} \right]$	n.a.

c = composite compound rate

d = composite discount rate

g = annual growth rate of payment

i = rate of interest (discount) in decimal form

n = number of years or periods until last payment

t = number of years between periodic payments

In other words, the overall effect of compounding at a rate (g) and discounting at a rate (i) (where $i < g$), is a compound effect equal to a rate (c). Depending upon the relationship between (i) and (g), either a (c) or a (d) is calculated and used in the appropriate formula shown in Table 10. Actually, it is not mathematically necessary to define a separate (c) for the case where $i < g$ since a negative (d) could be used in place of (c). However, it is more meaningful and useful to deal with positive rates defining a net effect of (i) and (g) as either a compound effect or a discount effect.

3.4 Using Composite Discount Formulas for Annual Payments

The use of the discount formulas found in Table 10 is demonstrated using the two alternate cash flows presented earlier, the Korea fuelwood case (Table 1) and the Mythopia example (Table 5). Table 11 is a modification of the Korea fuelwood analysis. Two of the original assumptions were changed. First, the real price of fuelwood was assumed to increase by 2 percent annually beginning in the first year. Second, the real wage of silvicultural labour was assumed to rise by 4 percent annually, also beginning in the first year.

The entries in the net benefit (cost) row of Table 11 have no consistent annual or periodic pattern, unlike the net benefit (cost) row of Table 1. It appears, then, that the NPW would be best determined by discounting each yearly entry back to year zero. However, an easier method exists. Table 12 illustrates the use of the annual payment factor, when the payment begins "next year", under the assumption of growth rates. The procedures used here are similar to the procedures used in Table 3, which are explained in Appendix 5. Each net benefit (cost) from Table 11 for years 0-20, except for years 7-19, is entered in column 3 as a net benefit (cost). In Table 12 the net benefits for years 7-19 have been split up into their three individual benefit and cost components, shown in rows 7-9. Column 4 shows the base year (year 7) value of each component. Fuelwood benefits are compounded at 2 percent annually, supervision cost is not compounded, and harvesting cost is compounded at 4 percent annually, as indicated by column 5. The composite discount rate (d) for each component is shown in column 6. Each single payment (rows 1, 3, 4, 5, 6 and 10) is discounted to year zero at a 10 percent discount rate ($i=10\%$) and entered into column 9. Each sequence of annual payments (rows 2, 7, 8 and 9) is discounted back to the year before the payment begins (the year is shown in column 7 and the discounted value in that year is shown in column 8). For the two annual payments without growth rates, the previously explained formula from Table 2 (row 1, column 1) was used (with $i=10\%$). For the other two annual payments (the ones which include growth rates), the formula from row 1, column 1 of Table 10 was used (where (d) equals the value in column 6). These discounted values are further discounted to year zero (using $i = 10\%$), and the resulting present value is indicated in column 9 of Table 12. The sum of all of these present values equals the NPW, which is W148.4.

The NPW of the Korea fuelwood cash flow (Table 11) was calculated in Table 12 using the "growth" discounted annual payment formula which assumes that payments begin in one year (row 1, column 1 of Table 10). An equally valid alternative is to use the "growth" discounted annual payment formula which assumes that payments begin immediately (row 1, column 3 of Table 10). This was done in Table 13 for the same cash flow (from Table 11). The only difference between Table 13 and Table 12 is that the discounted values of the four annual payments (rows 2, 7, 8 and 9) are expressed in terms of the base year instead of one year earlier. Therefore, only columns 7 and 8 differ between the two tables. These discounted values are further discounted to year zero (using $i = 10\%$), and the resulting present values are entered into column 9. Each entry in column 9 of Table 13 is, of course, identical to the corresponding entry in column 9 of Table 12.

The above may seem very complex and cumbersome. However, in practice, the modifications suggested reduce the complexity of the calculations needed to arrive at useable conceptually correct results, particularly when one is dealing with a fairly long project period.

3.5 Using Composite Discount Formulas for Periodic Payments

The use of discounted periodic payment formulas which assume growth rates can be demonstrated by using the cash flow exhibited in Table 14, which is a modification of the Mythopia cash flow (Table 5), used earlier to illustrate the use of periodic payment formulas. The same two growth rates assumed in Table 11 are also assumed in this case: the real price of fuelwood increases by 2 percent annually, beginning in the first year, and the real wage of silvicultural labour rises by 4 percent annually, also beginning in the first year.

The NPW of the Table 14 cash flow is calculated by separate methods in Table 15 and Table 16, which are constructed in the same format as Tables 12 and 13 discussed above. Each net benefit (cost) from Table 14 is either entered as a net benefit (cost) in column 3 of each table, or is broken down into component benefits and costs which are individually entered in column 4.⁷ In Table 15 the discounted values of the annual and periodic payments are expressed in terms of the year or period prior to the start of the payments (the years shown in column 7). The discounted values of the periodic payments of Table 15 were calculated using the formula from row 3, column 1 of Table 10. In Table 16 the discounted values of the annual and periodic payments are expressed in terms of the year in which the payments begin (the years shown in column 7 of Table 16). The discounted values of the periodic payments of Table 16 were calculated using the formula from row 3, column 3 of Table 10. The entries in column 9 of each table are the present values of the numbers in columns 3 or 8. These present values are, of course, the same in both tables since each table only illustrates a different method to calculate the same NPW.

In cases where one or more growth rates exceed the discount rate, the discounted annual and periodic payment factors from rows 5 and 7 of Table 10 would be applied in the same manner as described above. In such cases a composite compound rate (c) would be calculated instead of a composite discount rate (d). The same procedures and format used in Tables 12, 13, 15 and 16 could still be used.

⁷ In the cases where growth rates apply to these individual benefits and costs, the base year amount is entered into column 4.

Table 11 - Korea Fuelwood Cash Flow Analysis, Assuming Benefits Increase by Two Percent Annually and Harvesting Costs Increase by Four Percent Annually

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
[1] BENEFITS (fuelwood)	-	-	-	6.9	14.1	28.7	58.6	74.7	76.2	77.7	79.2	80.8	82.4	84.1	85.8	87.5	89.2	91.0	92.8	94.7	2414.7
[2] COSTS																					
[3] Establishment	130.0																				
[4] Supervision	2.4	2.4	2.4	3.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	
[5] Misc. (tools, etc.)	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
[6] Harvesting	-	-	-	2.1	4.3	9.1	19.0	24.6	25.6	26.6	27.7	28.8	29.9	31.1	32.4	33.7	35.0	36.4	37.9	39.4	2054.2
[7] Total Cost	139.9	2.4	2.4	4.5	6.7	11.5	21.4	27.0	28.0	29.0	30.1	31.2	32.3	33.5	34.8	36.1	37.4	38.8	40.3	41.8	2054.2
[8] NET BENEFIT (cost) (139.9) (2.4) (4.5) 2.4 7.4 17.2 37.2 47.7 48.2 48.7 49.1 49.6 50.1 50.6 51.0 51.4 51.8 52.2 52.5 55.6 362.5																					

1/
Table 12 - Calculation of Net Present Worth (NPW) for Korea Fuelwood Project When the Disc. Value of Annual Payment is Expressed in Terms of the Year Prior to First Payment

Item	Year	Net Benefit or (cost)	Base Year Amount	Individual Benefit or (Cost)			Discounted Value of Annual Payment Year	Present Worth (Year 0)
				[5]	[6]	[7]		
[1]	[2]	[3]	[4]					
[1] Net Cost	0	(139.9)						(139.900)
[2] Net Cost	1-2	2.4					0	(4.165)
[3] Net Benefit	3	2.4						1.803
[4] Net Benefit	4	7.4						5.054
[5] Net Benefit	5	17.2						10.680
[6] Net Benefit	6	37.2						20.998
[7] Fuelwood Benefit 7-19			74.7	2	7.843	6	583.863	329.575
[8] Supervision Cost 7-19			(2.4)	0	n.a.	6	(17.048)	(9.623)
[9] Harvesting Cost 7-19			(24.6)	4	5.769	6	(212.252)	(119.811)
[10] Net Benefit	20	362.5						53.833

Net Present Worth (NPW) = 148.4

1/
Table 13 - Calculation of Net Present Worth (NPW) for Korea Fuelwood Project When the Disc. Value of Annual Payment is Expressed in Terms of the Year in Which Payment Begins

Item	Year	Net Benefit or (cost)	Base Year Amount	Individual Benefit or (Cost)			Discounted Value of Annual Payment Year	Present Worth (Year 0)
				[5]	[6]	[7]		
[1]	[2]	[3]	[4]					
[1] Net Cost	0	(139.9)						(139.000)
[2] Net Cost	1-2	(2.4)					0	(4.582)
[3] Net Benefit	3	2.4						1.803
[4] Net Benefit	4	7.4						5.054
[5] Net Benefit	5	17.2						10.680
[6] Net Benefit	6	37.2						20.998
[7] Fuelwood Benefit 7-19			74.7	2	7.843	7	642.249	329.575
[8] Supervision Cost 7-19			(2.4)	0	n.a.	7	(18.753)	(9.623)
[9] Harvesting Cost 7-19			(24.6)	4	5.769	7	(233.477)	(119.811)
[10] Net Benefit	20	362.5						53.833

Net Present Worth (NPW) = 148.4

1/ Assuming benefits increase by 2% annually and harvesting costs increase by 4% annually

Table 14 - Mythopia Cash Flow Analysis, Assuming Benefits Increase by Two Percent Annually and Harvesting Costs by Four Percent Annually

	- Y E A R -																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
[1] BENEFITS (fuelwood)	-	-	-	-	35.2	-	146.4	-	152.3	-	158.5	-	164.9	-	171.5	-	178.5	-	185.7	-	2414.7
[2] COSTS																					
[3] Establishment	130.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
[4] Supervision	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	
[5] Misc. (tools, etc.)	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
[6] Harvesting	-	-	-	-	11.0	-	47.3	-	51.2	-	55.4	-	59.9	-	64.7	-	70.0	-	75.8	-	2054.2
[7] Total Cost	139.9	2.4	2.4	2.4	13.4	2.4	49.7	2.4	53.6	2.4	57.8	2.4	62.3	2.4	67.1	2.4	72.4	2.4	78.2	2.4	2054.2
[8] NET BENEFIT (cost) (139.9) (2.4) (2.4) 21.8 (2.4) 96.7 (2.4) 98.7 (2.4) 100.7 (2.4) 102.6 (2.4) 104.4 (2.4) 106.1 (2.4) 107.5 (2.4) 362.5																					

2/
Table 15 - Calculation of Net Present Worth (NPW) for Mythopia Project When Discounted Value of Annual/Periodic Payment is Expressed in Terms of Year Prior to First Payment (i=10%)

Item	Year ^{1/}	Individual Benefit or (Cost)			Discounted Value of Annual/Periodic Payment			Present Worth (Year 0)
		Net Benefit or (Cost)	Base Year Amount	Annual Growth Rate (%)	Composite Discount Rate (%)	Year	Value	
[1] Net Cost	0	(139.9)						(139.900)
[2] Supervision Cost	1-19		(2.4)	0	n.a.	0	(20.076)	(20.076)
[3] Fuelwood Benefit	4		35.2					24.042
[4] Harvesting Cost	4		(11.0)					(7.513)
[5] Fuelwood Benefit	6-18 (p)		146.4	2	7.843	4	563.277	384.726
[6] Harvesting Cost	6-18 (p)		(47.3)	4	5.769	4	(200.397)	(136.874)
[7] Net Benefit	20		362.5					53.833

Net Present Worth (NPW) = 158.2

2/
Table 16 - Calculation of Net Present Worth (NPW) for Mythopia Project When the Discounted Value of Annual/Periodic Payment is Expressed in Terms of Year in Which Pay. Begins (i=10%)

Item	Year ^{1/}	Individual Benefit or (Cost)			Discounted Value of Annual/Periodic Payment			Present Worth (Year 0)
		Net Benefit or (Cost)	Base Year Amount	Annual Growth Rate (%)	Composite Discount Rate (%)	Year	Value	
[1] Net Cost	0	(139.9)						(139.900)
[2] Supervision Cost	1-19		(2.4)	0	n.a.	6	(22.083)	(20.076)
[3] Fuelwood Benefit	4		35.2					24.042
[4] Harvesting Cost	4		(11.0)					(7.513)
[5] Fuelwood Benefit	6-18 (p)		146.4	2	7.843	6	681.565	384.726
[6] Harvesting Cost	6-18 (p)		(47.3)	4	5.769	6	(242.481)	(136.874)
[7] Net Benefit	20		362.5					53.833

Net Present Worth (NPW) = 158.2

1/ "(p)" refers to periodic payment occurring every two years

2/ Assuming benefits increase by 2% annually and harvesting costs increase by 4% annually

4. UNCERTAINTY AND TIME CONSIDERATIONS ^y

A usual point made about uncertainty (and risk) is that the further into the future a given event occurs the more uncertain is that event. For example, in projecting future stumpage prices, we can be fairly confident that an estimate of next year's price will be reasonably accurate unless totally unforeseen major events occur to disrupt trends. Such events are also less likely in a shorter period. We cannot be nearly as confident about stumpage price estimates 30 years from now. The same holds for final or intermediate product prices and for costs.

However, at the same time, errors in far future estimates are less important in NPW or ROR calculations than errors in near future estimates. The degree of importance depends on a) the discount rate used in NPW calculations, b) the project's implied ROR, and c) the period of years between the present and the year to which the estimate applies.

For example, assume an estimated stumpage price for pine of $\$30/m^3$ some 40 years from now. A 20 percent error would put the range between $\$24$ and $\$36$ per m^3 , or $\$6$ on either side of the best estimate. However, in present value terms, discounting at 10 percent, the range would appear as follows:

Low	Best	High
$\$0.53/m^3$	$\$0.66/m^3$	$\$0.80/m^3$

In other words, looked at in present value terms, the spread between high and low estimates is only $\$0.80 - \0.53 or $\$0.27/m^3$, as compared to $\$12.00/m^3$ in future or current value terms. (The difference, of course, is still 20 percent.) What looks like a large difference in absolute terms 40 years from now is a relatively small absolute difference in PV terms.

But now, suppose we had a faster growing plantation and we estimated a stumpage price of $\$20/m^3$ some 15 years from now. The present value, at 10 percent, would be $\$4.79/m^3$ and the range with a 20 percent error would be from $\$3.83 - \5.75 per m^3 or a spread of $\$1.92/m^3$ in PV terms between high and low.

In this case, holding the discount rate constant, we can see that a given absolute (or percentage) error in an estimate is more important, in PV terms, the closer it occurs to the present. ^{2/} Conversely, using a higher discount rate reduces the importance of an error in estimate of a value that occurs at a given time in the future.

In sum, on the one hand, uncertainty concerning estimates of future values tends to increase the further into the future we go. On the other hand, the further into the future a given value or event occurs, the less we have to be concerned about reducing the uncertainty surrounding the estimate of that value or event, because its impact on NPW or ROR will be less.

^y See EAFF, Chapter 10, which deals with treatment of risk and uncertainty in project planning. Here we merely want to relate the subject to time considerations.

^{2/} Obviously, if the error is estimated for year zero prices, the PV of the error will be the same as its current value.

Appendix I

Treatment of Annual and Periodic Payments

Geometric series

Compounded and discounted annual and periodic payment factors, capital recovery factors, and sinking fund factors are all derived from the expression for the sum of a geometric series. For any non-zero real numbers; (a) and (k), and for non-negative integers, (y) and (n), the following series is denoted:

$$\sum_{y=0}^n ak^y = a + ak + ak^2 + \dots + ak^y + \dots + ak^n$$

Then:

$$K \sum_{y=0}^n ak^y = ak + ak^2 + ak^3 + \dots + ak^y + ak^{y+1} + \dots + ak^n + ak^{n+1}$$

Therefore:

$$\left[\sum_{y=0}^n ak^y \right] - K \left[\sum_{y=0}^n ak^y \right] = a - ak^{n+1}$$
$$\left[\sum_{y=0}^n ak^y \right] (1-K) = a(1-K^{n+1})$$

(1)

$$\sum_{y=0}^n ak^y = a \left[\frac{1-K^{n+1}}{1-K} \right]$$

Using the same notations above but excluding the first term of the series, the following series is denoted:

$$\sum_{y=1}^n ak^y = ak + ak^2 + \dots + ak^y + \dots + ak^n$$
$$= a \left[\frac{1-K^{n+1}}{1-K} - 1 \right]$$
$$= a \left[\frac{1-K^{n+1} - 1+K}{1-K} \right]$$

(2)

$$\sum_{y=1}^n ak^y = a \left[\frac{K(1-K^n)}{1-K} \right]$$

Determination of present value factors and future value factors for annual payments beginning "next year"

The discounted annual payment factor can be derived from either equation 1 or equation 2, depending upon when the annual payment begins. Most texts refer to the second case, i.e., payments beginning "next year" and continuing for a total of n years. Therefore, this is the case derived below (from equation 2). Once that factor has been determined, it is much easier to derive the first case (when the payment begins "this year" and continues for n more years) by using the case 2 factor rather than equation 1.

Let: a = annual payment beginning next year and continuing for a total of n years

n = number of annual payments (also equals the number of years until the last payment)

i = rate of interest (discount)

y = any given year

Then, the series, $\frac{a}{1+i} + \frac{a}{(1+i)^2} + \dots + \frac{a}{(1+i)^n} + \frac{a}{(1+i)^{n+1}}$, equals the present value of an annual payment (a) received next year and continuing for n years. Substituting $\frac{a}{1+i}$ for k in equation 2, the following equation results:

$$\sum_{y=1}^n \frac{a}{(1+i)^y} = a \left[\frac{\frac{1}{(1+i)} \left[1 - \frac{1}{(1+i)^n} \right]}{1 - \frac{1}{(1+i)}} \right]$$

Multiplying the numerator and denominator by $\frac{(1+i)^{n+1}}{(1+i)^{n+1}}$:

$$= a \left[\frac{(1+i)^n \left[1 - \frac{1}{(1+i)^n} \right]}{(1+i)^{n+1} - (1+i)^n} \right]$$

$$= a \left[\frac{(1+i)^n - 1}{(1+i)^n (1+i-1)} \right]$$

$$(3) \quad \sum_{y=1}^n \frac{a}{(1+i)^y} = a \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right]$$

DISCOUNTED ANNUAL PAYMENT FACTOR
(payment starting "next year")

The future value (in year n) of an annual payment (a) received next year and continuing for a total of n years is derived from equation 3 as follows:

$$\sum_{y=0}^{n-1} a(1+i)^y = a + a(1+i) + a(1+i)^2 + \dots + a(1+i)^y + \dots + a(1+i)^{n-2} + a(1+i)^{n-1}$$

$$= a \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] (1+i)^n$$

$$(4) \quad \sum_{y=0}^{n-1} a(1+i)^y = a \left[\frac{(1+i)^n - 1}{i} \right]$$

COMPOUND ANNUAL PAYMENT FACTOR
(payment starting "next year")

Determination of present value factors and future value factors for annual payments beginning this year.
Using equation 3, the case 1 factor (the present value of an annual payment beginning this year and continuing for n more years) is derived as follows:

Let: a = annual payment beginning this year and continuing for n more years
n = number of years until last payment (there are n+1 payments)
i = rate of interest (discount)
y = any given year

Then:

$$\sum_{y=0}^n \frac{a}{(1+i)^y} = a + \frac{a}{(1+i)} + \frac{a}{(1+i)^2} + \dots + \frac{a}{(1+i)^y} + \dots + \frac{a}{(1+i)^n}$$

$$(5a) \quad \sum_{y=0}^n \frac{a}{(1+i)^y} = a \left[1 + \frac{(1+i)^n - 1}{i(1+i)^n} \right]$$

$$= a \left[\frac{i(1+i)^n + (1+i)^n - 1}{i(1+i)^n} \right]$$

$$= a \left[\frac{(1+i)^n (i+1) - 1}{i(1+i)^n} \right]$$

DISCOUNTED ANNUAL PAYMENT FACTOR (Form a)
(payment starting "this year")

$$(5b) \quad \sum_{y=0}^n \frac{a}{(1+i)^y} = a \left[\frac{(1+i)^{n+1} - 1}{i(1+i)^n} \right]$$

DISCOUNTED ANNUAL PAYMENT FACTOR (Form b)
(payment starting "this year")

Equation 5a is generally easier to remember (especially in relation to equation 3). And when using an electronic calculator which automatically gives on the "next year" (equation 3) form, equation 5a is easier to use. However, equation 5b is easier to use with an electronic calculator which doesn't automatically do compounding and discounting.

As before the compounded factor can be easily derived from the discounted factor. The future value (in year n) of an annual payment (a) received this year and continuing for n more years is derived from equations 5a and 5b as follows:

$$\sum_{y=0}^n a(1+i)^y = a + a(1+i) + a(1+i)^2 + \dots + a(1+i)^y + \dots + a(1+i)^{n-1} + a(1+i)^n$$

Using equation 5a:

$$= a \left[\frac{1 + (1+i)^n - 1}{i(1+i)^n} \right] (1+i)^n$$

$$(6a) \quad \sum_{y=0}^n a(1+i)^y = a \left[\frac{(1+i)^n + (1+i)^n - 1}{i} \right]$$

COMPOUNDED ANNUAL PAYMENT FACTOR (Form a)
(payment starting "this year")

Using equation 5b:

$$= a \left[\frac{(1+i)^{n+1} - 1}{i(1+i)^n} \right] (1+i)^n$$

$$(6b) \quad \sum_{y=0}^n a(1+i)^y = a \left[\frac{(1+i)^{n+1} - 1}{i} \right]$$

COMPOUNDED ANNUAL PAYMENT FACTOR (Form b)
(payment starting "this year")

As was the case with equation 5a, it may again be easier to remember equation 6a since it is composed of the sum of the future value of an annual payment beginning next year (and continuing for a total of n years) and the future value of a single payment made this year. However, equation 6b is as simple or simpler to use with electronic calculators.

Annual capital recovery factors and sinking fund factors

Two other useful factors can be derived from preceding equations. The capital recovery factor (equation 7) is the inverse of the discounted annual payment factor (when payment starts "next year"), equation 3. The sinking fund factor (equation 8) is the inverse of the compounded annual payment factor (when payment starts "next year"), equation 4.

$$(7) \quad a = \sum_{y=1}^n \frac{a}{(1+i)^y} \left[\frac{1(1+i)^n}{(1+i)^n - 1} \right] \quad \text{ANNUAL CAPITAL RECOVERY FACTOR}$$

$$(8) \quad a = \sum_{y=0}^{n-1} a(1+i)^y \left[\frac{1}{(1+i)^n - 1} \right] \quad \text{ANNUAL SINKING FUND FACTOR}$$

Determination of present value factors and future value factors for periodic payments beginning "next period"

Compound and discounted periodic payment factors can also be derived from equation 2. The present value of a periodic (every t years) payment (a) is derived below.

Let: a = periodic payment beginning in t years and continuing every t years for a total of n periods

t = time interval between periods

n = number of periodic payments (nt equals the number of years until the last payment)

i = rate of annual interest (discount)

y = any given period (yt equals any given year in which a payment occurs)

Then the series, $\frac{a}{(1+i)^t} + \frac{a}{(1+i)^{2t}} + \frac{a}{(1+i)^{3t}} + \dots + \frac{a}{(1+i)^{yt}} + \dots + \frac{a}{(1+i)^{nt}}$, equals the present value of a periodic payment. Substituting a composite periodic discount rate (p) equal to the rate of discount per period rather than per year, the same steps can be followed as were followed in the derivation of equation 3.

1/ Capital recovery and sinking fund factors are generally not meaningful in practical applications when payments begin "this year." However, they are theoretically as meaningful as equations 7 and 8 (derived below), and may have some practical use as well. These factors would be the reciprocals of equations 5b and 6b, respectively.

First p is defined: $p = (1+i)^t - 1$; $(1+p) = 1+i$

Then, substituting $(1+p) = (1+i)^t$, the series,

$$\frac{a}{(1+p)} + \frac{a}{(1+p)^2} + \frac{a}{(1+p)^3} + \dots + \frac{a}{(1+p)^y} + \dots + \frac{a}{(1+p)^n},$$

is obtained, which is in the same form as the discount annual payment factor series. Therefore, equation 3 can be derived as shown earlier, but this time using p instead of i ,

$$\sum_{y=1}^n \frac{a}{(1+p)^y} = a \left[\frac{(1+p)^n - 1}{p(1+p)^n} \right]$$

Substituting, $p = (1+i)^t - 1$, and $(1+i)^t = (1+p)$

$$(9) \quad \sum_{y=1}^n \frac{a}{(1+i)^{yt}} = a \left[\frac{(1+i)^{nt} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] \quad \begin{array}{l} \text{DISCOUNTED PERIODIC} \\ \text{PAYMENT FACTOR} \\ (\text{payment starting in } t \text{ years}) \end{array}$$

The future value (in year nt) of a periodic payment (a) received in the next period (in t years) and continuing every t years for a total of n periods is derived from equation 9 as follows:

$$\begin{aligned} \sum_{y=0}^{n-1} a(1+i)^{yt} &= a + a(1+i)^t + a(1+i)^{2t} + \dots + a(1+i)^{yt} + \dots + a(1+i)^{(n-2)t} + a(1+i)^{(n-1)t} \\ &= a \left[\frac{(1+i)^{nt} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] (1+i)^{nt} \end{aligned}$$

$$(10) \quad \sum_{y=0}^{n-1} a(1+i)^{yt} = a \left[\frac{(1+i)^{nt} - 1}{(1+i)^t - 1} \right] \quad \begin{array}{l} \text{COMPOUNDED PERIODIC} \\ \text{PAYMENT FACTOR} \\ (\text{payment starting in } t \text{ years}) \end{array}$$

Determination of present value factors and future value factors for periodic payments beginning "this year" Using equation 9, the present value of a periodic payment beginning this year and continuing every t years for n more periods is derived as follows:

Let: a = periodic payment beginning this year and continuing every t years for n more periods

t = time interval between periods

n = number of periodic payments after first payment (there are $n+1$ payments and nt equals the number of years until the last payment)

i = rate of annual interest (discount)

y = any given period (yt equals any given year in which a payment occurs)

$$\text{Then: } \sum_{y=0}^n \frac{a}{(1+i)^{yt}} = a + \frac{a}{(1+i)^t} + \frac{a}{(1+i)^{2t}} + \frac{a}{(1+i)^{3t}} + \dots + \frac{a}{(1+i)^{yt}} + \dots + \frac{a}{(1+i)^{nt}}$$

$$\begin{aligned} \sum_{y=0}^n \frac{a}{(1+i)^{yt}} &= a \left[1 + \frac{(1+i)^{nt} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] \\ &= a \left[\frac{(1+i)^{nt} [(1+i)^t - 1] + (1+i)^{nt} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] \\ &= a \left[\frac{(1+i)^{nt} [(1+i)^t - 1 + 1] - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] \end{aligned}$$

$$(11) \sum_{y=0}^n \frac{a}{(1+i)^{yt}} = a \left[\frac{(1+i)^{(nt+t)} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right]$$

DISCOUNTED PERIODIC
PAYMENT FACTOR
(payment starting "this year")

Again, as before the compounded factor can be easily derived from the discounted factor. The future value (in year nt) of a periodic payment (a) received this year and continuing every t years for n more periods is derived from equation 11 as follows:

$$(12) \sum_{y=0}^n a(1+i)^{yt} = a + a(1+i)^t + a(1+i)^{2t} + \dots + a(1+i)^{yt} + \dots + a(1+i)^{(n-1)t} + \dots + a(1+i)^{nt}$$

$$= a \left[\frac{(1+i)^{(nt+t)} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] (1+i)^{nt}$$

$$\sum_{y=0}^n a(1+i)^{yt} = a \left[\frac{(1+i)^{(nt+t)} - 1}{(1+i)^t - 1} \right]$$

COMPOUNDED PERIODIC
PAYMENT FACTOR
(payment starting "this year")

Periodic capital recovery factors and sinking fund factors

Theoretically, periodic capital recovery factors and periodic sinking fund factors are possible. They would be derived analogously to equations 7 and 8 from equations 9 and 10, respectively. However, in practice they are not in general use.

Determination of "infinite" factors

When annual or periodic payments continue for an infinite period (or for a sufficiently long finite period such that the "next" payment has no measurable present value) the equations for present values of such payments become much simplified. Four equations described in the preceding paragraphs can be simplified, equations 3, 5b, 9 and 11.

$$(3) \sum_{y=1}^n \frac{a}{(1+i)^y} = a \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] = a \left[\frac{1}{i} - \frac{1}{(1+i)^n} \right]$$

FINITE
DISCOUNTED ANNUAL
PAYMENT FACTOR
(payment starting "next year")

When $n \rightarrow \infty$, the second term $\left(\frac{1}{(1+i)^n} \right)$ approaches zero, leaving $\left[\frac{1}{i} \right]$.

$$(13) \sum_{y=1}^{\infty} \frac{a}{(1+i)^y} = a \left[\frac{1}{i} \right]$$

INFINITE
DISCOUNTED ANNUAL
PAYMENT FACTOR
(payment starting "next year")

$$(5b) \sum_{y=0}^n \frac{a}{(1+i)^y} = a \left[\frac{(1+i)^{n+1} - 1}{i(1+i)^n} \right] = a \left[\frac{1+i}{i} - \frac{1}{i(1+i)^n} \right]$$

FINITE
DISCOUNTED ANNUAL
PAYMENT FACTOR
(payment starting "this year")

When $n \rightarrow \infty$, the second term $\left[\frac{1}{i(1+i)^n} \right]$ approaches zero, leaving $\left[\frac{1+i}{i} \right]$.

$$(14) \sum_{y=0}^{\infty} \frac{a}{(1+i)^y} = a \left[\frac{1+i}{i} \right] \text{ or } a \left[1 + \frac{1}{i} \right]$$

INFINITE
DISCOUNTED ANNUAL
PAYMENT FACTOR
(payment starting "this year")

$$(9) \sum_{y=1}^n \frac{a}{(1+i)^{yt}} = a \left[\frac{(1+i)^{nt} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] = a \left[\frac{1}{(1+i)^t - 1} - \frac{1}{(1+i)^{nt} [(1+i)^t - 1]} \right]$$

When $n \rightarrow \infty$, the second term $\left[\frac{1}{(1+i)^{nt} [(1+i)^t - 1]} \right]$ approaches zero, leaving $\left[\frac{1}{(1+i)^t - 1} \right]$.

$$(15) \sum_{y=1}^{\infty} \frac{a}{(1+i)^{yt}} = a \left[\frac{1}{(1+i)^t - 1} \right]$$

INFINITE
DISCOUNTED PERIODIC
PAYMENT FACTOR
(payment starting in t years)

$$(11) \sum_{y=0}^n \frac{a}{(1+i)^{yt}} = a \left[\frac{(1+i)^{(nt+t)} - 1}{(1+i)^{nt} [(1+i)^t - 1]} \right] = a \left[\frac{(1+i)^t}{(1+i)^t - 1} - \frac{1}{(1+i)^{nt} [(1+i)^t - 1]} \right]$$

FINITE
DISCOUNTED PERIODIC
PAYMENT FACTOR
(payment starting in t years)

When $n \rightarrow \infty$, the second term $\left[\frac{1}{(1+i)^{nt} [(1+i)^t - 1]} \right]$ approaches zero, leaving $\left[\frac{(1+i)^t}{(1+i)^t - 1} \right]$.

$$(16) \sum_{y=0}^{\infty} \frac{a}{(1+i)^{yt}} = a \left[\frac{(1+i)^t}{(1+i)^t - 1} \right]$$

INFINITE
DISCOUNTED PERIODIC
PAYMENT FACTOR
(payment starting "this year")

Appendix 2

Treatment of Annual and Periodic Payments When Payments Grow Annually

Determination of present value factors and future value factors for annual payments beginning "next year"

The usual case for a series representing the present value of annual payments beginning "next year" and continuing for a total of n years is: ^{1/}

$$\sum_{y=1}^n \frac{a}{(1+i)^y} = \frac{a}{(1+i)} + \frac{a}{(1+i)^2} + \dots + \frac{a}{(1+i)^y} + \dots + \frac{a}{(1+i)^n}$$

where, a = annual payment beginning next year and continuing for a total of n years.

n = number of annual payments (also equals the number of years until the last payment)

i = rate of interest (discount)

y = any given year

However, this only represents the special case (perhaps the most common case) when (a) remains constant. Often an annual payment (beginning "next year") would increase at an annual rate (g) , such that the following sequence would result. ^{2/}

$$a, a(1+g), a(1+g)^2, \dots, a(1+g)^{y-1}, \dots, a(1+g)^{n-1}$$

The present value of all (n) payments is represented by the following series:

$$\frac{a}{(1+i)} + \frac{a(1+g)}{(1+i)^2} + \frac{a(1+g)^2}{(1+i)^3} + \dots + \frac{a(1+g)^{y-1}}{(1+i)^y} + \dots + \frac{a(1+g)^{n-1}}{(1+i)^n}$$

Factoring out $\left[\frac{a}{1+g}\right]$, the series becomes:

$$\left[\frac{a}{1+g}\right] \left[\frac{1+g}{1+i}\right] + \left[\frac{a}{1+g}\right] \left[\frac{1+g}{1+i}\right]^2 + \left[\frac{a}{1+g}\right] \left[\frac{1+g}{1+i}\right]^3 + \dots + \left[\frac{a}{1+g}\right] \left[\frac{1+g}{1+i}\right]^y + \dots + \left[\frac{a}{1+g}\right] \left[\frac{1+g}{1+i}\right]^n$$

Three possible relationships exist between (i) and (g) :

1. If $i > g$, then a composite discount rate (d) can be defined.

2. If $i = g$, then a direct summing of terms is possible, and the present value of the payments becomes: $n \left[\frac{a}{1+g}\right] (1+i)^n$ while the future value of the payments becomes: $n \left[\frac{a}{1+g}\right] (1+g)^n$.

3. If $i < g$, then a composite compound rate (c) can be defined.

The composite discount rate (d) equals: $\left[\frac{(1+i)}{(1+g)} - 1\right]$.

Substituting $\left[\frac{1}{1+d}\right]$ into the above series for $\left[\frac{1+g}{1+i}\right]$, the following series results:

$$\left[\frac{a}{1+g}\right] \left[\frac{1}{1+d}\right] + \left[\frac{a}{1+g}\right] \left[\frac{1}{(1+d)^2}\right] + \left[\frac{a}{1+g}\right] \left[\frac{1}{(1+d)^3}\right] + \dots + \left[\frac{a}{1+g}\right] \left[\frac{1}{(1+d)^y}\right] + \dots + \left[\frac{a}{1+g}\right] \left[\frac{1}{(1+d)^n}\right]$$

This series is in the same form as the series used to develop equation 3 in Appendix 1. Instead of annual payment (a) and discount rate (i) , there is annual payment $\left[\frac{a}{1+g}\right]$ and composite discount rate (d) . Therefore, the following equation (analogous to equation 3 in Appendix 1) for the present value of a string of annual payments can be derived:

$$\sum_{y=1}^n \left[\frac{a}{1+g}\right] = \frac{a}{1+g} \left[\frac{(1+d)^n - 1}{d(1+d)^n} \right]$$

1/ See Appendix 1, page 2.

2/ The rate (g) could also represent an annual decrease in (a) . In that case (g) would be negative. If two or more growth rates affected (a) , (g) would be a composite of all growth rates.

$$(A) \sum_{y=1}^n \frac{\left[\frac{a}{1+g}\right]}{(1+d)^y} = a \left[\frac{(1+d)^n - 1}{d(1+d)^n (1+g)} \right]$$

$\frac{1+g}{d}$
DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "next year")

The future value equation is derived from equation A as follows:

$$\sum_{y=0}^{n-1} a(1+g)^{n-y-1} (1+i)^y = a(1+g)^{n-1} + a(1+g)^{n-2} (1+i) + a(1+g)^{n-3} (1+i)^2 + \dots + a(1+g)^{n-y-1} (1+i)^y + \dots$$

$$+ a(1+g)(1+i)^{n-2} + a(1+i)^{n-1}$$

$$\sum_{y=0}^{n-1} \left[\frac{a(1+g)^{n-1} (1+i)^y}{(1+g)^y} \right] = \sum_{y=0}^{n-1} a(1+g)^{n-1} (1+d)^y = a \left[\frac{(1+d)^n - 1}{d(1+d)^n (1+g)} \right] (1+i)^n$$

$$= a \left[\frac{(1+i)^n \left[(1+d)^n - 1 \right]}{d \left[\frac{(1-i)^n}{(1+g)^n} \right] (1+g)} \right]$$

$$(B) \sum_{y=0}^{n-1} a(1+g)^{n-1} (1+d)^y = a \left[\frac{(1+g)^{n-1} \left[(1+d)^n - 1 \right]}{d} \right]$$

$\frac{1+g}{d}$
COMPOUNDED ANNUAL PAYMENT FACTOR
(payment begins "next year")

The composite compound rate (c) equals $\left[\frac{(1+g)}{1+i} - 1 \right]^{1/1}$

Substituting (1+c) into the original series for $\left[\frac{1+g}{1+i} \right]$, the following series results:

$$\left[\frac{a}{1+g} \right] (1+c) + \left[\frac{a}{1+g} \right] (1+c)^2 + \left[\frac{a}{1+g} \right] (1+c)^3 + \dots + \left[\frac{a}{1+g} \right] (1+c)^y + \dots + \left[\frac{a}{1+g} \right] (1+c)^n$$

This series is in the same form as the series used to develop equations 6a and 6b in Appendix 1. Substituting $\left[\frac{a}{1+g} \right]$ for (a), and (d) for (1), except that the first term is "missing".^{2/} Therefore, using equation 6b from Appendix 1, the present value of a string of annual payments beginning next year is derived.

$$\sum_{y=1}^n \left[\frac{a}{1+g} \right] (1+c)^y = \left[\frac{a}{1+g} \right] \left[\frac{(1+c)^{n+1} - 1}{c} - 1 \right]$$

$$= a \left[\frac{(1+c)^{n+1} - 1 - c}{c (1+g)} \right]$$

$$= a \left[\frac{(1+c)^n \left[(1+c) - 1 \right]}{c (1+g)} \right]$$

$$= a \left[\frac{\frac{1+g}{1+i} \left[(1+c)^n - 1 \right]}{c (1+g)} \right]$$

$$(C) \sum_{y=1}^n \left[\frac{a}{1+g} \right] (1+d)^y = a \left[\frac{(1+c)^n - 1}{c (1+i)} \right]$$

$\frac{1+g}{c}$
DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "next year")

1/ It is not mathematically necessary to define a separate composite compound rate (c). The composite discount rate (d) is sufficient if one is willing to work with negative d's in such cases. However, in practice it is more meaningful to work with positive compound and discount rates.

2/ The series developed here is a present value of an annual payment which "grows" by a higher rate than the discount rate. Therefore, the present value of each successive year's payment increases. This results in a series of the same form as the series representing the compounded annual payment factor when $n = 0$.

The future-value form of equation C is derived in the manner of equation B, using the same series, repeated below:

$$\sum_{y=0}^{n-1} a (1+g)^{n-y-1} (1+i)^y = a(1+g)^{n-1} + a(1+g)^{n-2} (1+i) + a(1+g)^{n-3} (1+i)^2 + \dots + a(1+g)^{n-y-1} (1+i)^y + \dots$$

$$\sum_{y=0}^{n-1} \left[\frac{a(1+g)^{n-1} (1+i)^y}{(1+g)^y} \right] = a \left[\frac{(1+i)^n - 1}{c(1+i)} \right] (1+i)^n$$

$$(D) \sum_{y=0}^{n-1} \left[\frac{a(1+g)^{n-1}}{(1+i)^y} \right] = a \left[\frac{(1+i)^{n-1} \left[(1+i)^n - 1 \right]}{c} \right]$$

$\frac{1 < g}{\text{COMPOUNDED ANNUAL PAYMENT FACTOR}}$
(payment begins "next year")

Determination of present value factors and future value factors for annual payments beginning "this year"

The usual case for a series representing the present value of annual payments beginning "this year" and continuing for n more years is: $\frac{1}{1}$

$$\sum_{y=0}^{n-1} \frac{a}{(1+i)^y} = a + \frac{a}{(1+i)} + \frac{a}{(1+i)^2} + \dots + \frac{a}{(1+i)^y} + \dots + \frac{a}{(1+i)^n}$$

where, a = annual payment beginning this year and continuing for n more years
 n = number of years until last payment (there are $n+1$ payments)
 i = rate of interest (discount)
 y = any given year

However, again this only represents the special case when (a) remains constant. When (a) increases at a rate (g) each year, the following sequence results: $\frac{2}{2}$

$$a, a(1+g), a(1+g)^2, \dots, a(1+g)^y, \dots, a(1+g)^n$$

The present value of all $(n+1)$ payments is represented by the following series:

$$a + a \left[\frac{(1+g)}{(1+i)} \right] + a \left[\frac{(1+g)^2}{(1+i)^2} \right] + \dots + a \left[\frac{(1+g)^y}{(1+i)^y} \right] + \dots + a \left[\frac{(1+g)^n}{(1+i)^n} \right]$$

As before, three possible relationships exist between (i) and (g) .

1. If $i > g$, then a composite discount rate (d) can be defined.
2. If $i = g$, then a direct summing of terms is possible, and the present value of the payments becomes $a(n+1)$, while the future value of the payments becomes $a(n+1)(1+i)^n$.
3. If $i < g$, then a composite compound rate (c) can be defined.

1/ See Appendix 1, page 2.

2/ The rate (g) could also represent an annual decrease in (a) . In that case (g) would be negative. If two or more growth rates affected (a) , (g) would be a composite of all growth rates.

Again, the composite discount rate (d) equals: $\left[\frac{(1+i)}{(1+g)} - 1 \right]$.

Substituting $\left[\frac{1}{(1+d)} \right]$ into the above series for $\left[\frac{1+i}{1+g} \right]$, the following series results:

$$a + \frac{a}{(1+d)} + \frac{a}{(1+d)^2} + \dots + \frac{a}{(1+d)^y} + \dots + \frac{a}{(1+d)^n}$$

This series is in the same form as the series used to develop equation 5b in Appendix 1, except that (d) has replaced (i). Therefore, the following equation (analogous to equation 5b in Appendix 1) for the present value of a string of annual payments can be derived:

$$(E) \sum_{y=0}^n \frac{a}{(1+d)^y} = a \left[\frac{(1+d)^{n+1} - 1}{d(1+d)^n} \right]$$

$\frac{i>g}{\text{DISCOUNTED ANNUAL PAYMENT FACTOR}} \\ (\text{payment starting "this year"})$

The future value equation is derived from equation E as follows:

$$\sum_{y=0}^n a(1+g)^{n-y} (1+i)^y = a(1+g)^n + a(1+g)^{n-1} (1+i) + a(1+g)^{n-2} (1+i)^2 + \dots + a(1+g)^{n-y} (1+i)^y + \dots + a(1+g)^0 (1+i)^n$$

$$\sum_{y=0}^n \left[\frac{a(1+g)^n (1+i)^y}{(1+g)^y} \right] = a \left[\frac{(1+d)^{n+1} - 1}{d(1+d)^n} \right] (1+i)^n$$

$$\sum_{y=0}^n a(1+g)^n (1+d)^y = a \left[\frac{(1+i)^n \left[(1+d)^{n+1} - 1 \right]}{d(1+d)^n} \right]$$

$$= a \left[\frac{(1+i)^n \left[(1+d)^{n+1} - 1 \right]}{d \left[\frac{(1+i)^n}{(1+g)^n} \right]} \right]$$

$$(F) \sum_{y=0}^n a(1+g)^n (1+d)^y = a \left[\frac{(1+i)^n \left[(1+d)^{n+1} - 1 \right]}{d} \right]$$

$\frac{i>g}{\text{COMPOUNDED ANNUAL PAYMENT FACTOR}} \\ (\text{payment starting "this year"})$

The composite compound rate (c) again equals: $\left[\frac{(1+g)}{(1+i)} - 1 \right] = \frac{1}{1}$

Substituting (1+c) into the original series (p. 3 of this appendix) for $\left[\frac{1+g}{1+i} \right]$, the following series results:

$$a + a(1+c) + a(1+c)^2 + \dots + a(1+c)^y + \dots + a(1+c)^n$$

This series is in the same form as the series used to develop equations 6a and 6b in Appendix 1. (substituting "c" for "i"). ^{2/} Therefore, using equation 6b from Appendix 1, the present value of a string of annual payments beginning this year can be derived.

$$(G) \sum_{y=0}^n a(1+c)^y = a \left[\frac{(1+c)^{n+1} - 1}{c} \right]$$

$\frac{i<g}{\text{DISCOUNTED ANNUAL PAYMENT FACTOR}} \\ (\text{payment begins "this year"})$

1/ See footnote 1, p2 of this appendix.

2/ See footnote 2, p2 of this appendix.

The future value form of equation G is derived in the manner of equation F, using the same series, repeated below:

$$\sum_{y=0}^n a(1+g)^{n-y} (1+i)^y = a(1+g)^n + a(1+g)^{n-1} (1+i) + a(1+g)^{n-2} (1+i)^2 + \dots + a(1+g)^{n-y} (1+i)^y + \dots + a(1+g)(1+i)^{n-1} + a(1+i)^n$$

$$\sum_{y=0}^n \left[\frac{a(1+g)^n (1+i)^y}{(1+g)^y} \right] = a \left[\frac{(1+i)^{n+1} - 1}{i} \right] (1+i)^n$$

$$(H) \sum_{y=0}^n \frac{a(1+g)^n}{(1+i)^y} = a \left[\frac{(1+i)^n [(1+i)^{n+1} - 1]}{i} \right]$$

i < g
COMPOUNDED ANNUAL PAYMENT FACTOR
(payment begins "this year")

Annual capital recovery factors and sinking fund factors

Capital recovery factors and sinking fund factors generally do not consider growth rates. They are only affected by the interest rate (*i*), the number of payments (*n*), and the total amount of current or future principal to be repaid or accumulated. It is true that (*i*) might either be defined to be a real rate or a rate which includes an expectation of the average rate of inflation over the period. If (*i*) is defined as a real rate, the real value of each period's payment (*a*) would have to be multiplied by an inflation factor $(CPI_y / CPI_0)^{1/2}$, to get the nominal value which would then equalize the real value of each payment. If (*i*) is defined to include inflation, each period's payment (*a*) would be equal in nominal terms, but each successive payment would decline in real value. In such a case, a real rate of discount could be used with a negative (*g*) used to represent the annual decline in the value of (*a*) (which would be defined in nominal - not real-terms). Then (*g*) could be used in the manner described in this appendix. Capital recovery factors and sinking fund factors which include (*g*) would be the reciprocals of the discounted annual payment factors and the compounded annual payment factors, respectively (applying the same conditions as do these equations, namely, the "i:g" relationship and the year in which payment begins). However, when one is not working in real value terms, using a negative (*g*) to represent the annual decline in real value caused by inflation is much more difficult than defining (*i*) to include inflation and using the simpler equations developed in Appendix 1. ^{2/}

Determination of present value factors and future value factors for periodic payments beginning "next period"

The usual case for a series representing the present value of periodic payments beginning in *t* years and continuing every *t* years for a total of *n* periods is: ^{3/}

$$\sum_{y=t}^n \frac{a}{(1+i)^{yt}} = \frac{a}{(1+i)^t} + \frac{a}{(1+i)^{2t}} + \dots + \frac{a}{(1+i)^{yt}} + \dots + \frac{a}{(1+i)^{nt}}$$

Where, *a* = periodic payment beginning in *t* years and continuing every *t* years for a total of *n* periods
t = time interval between periods
n = number of periodic payments (*nt* equals number of years until last payment)
i = rate of annual interest (discount)
y = any given period (*yt* equals any given year in which a payment occurs)

However, this only represents the special case when (*a*) remains constant. When (*a*) increases at a rate (*g*) each year the following sequence results: ^{4/}

- 1/ Consumer price index for year (*y*) divided by consumer price index for year zero.
- 2/ If: *r*=real rate of interest and *f*=inflation rate, $(1+r)(1+f)-1=i$, the composite rate of interest which includes inflation. Defining a negative (*g*), $g=f/(1+f)$, is unnecessary and more complicated to apply.
- 3/ See Appendix 1, page 3.
- 4/ The rate (*g*) could also represent an annual decrease in (*a*). In that case (*g*) would be negative. If two or more growth rates affected (*a*), (*g*) would be a composite of all growth rates.

$$a, a(1+g)^t, a(1+g)^{2t}, \dots, a(1+g)^{(y-1)t}, \dots, a(1+g)^{(n-1)t}$$

The present value of all (n) payments is represented by the following series:

$$\frac{a}{(1+i)^t} + \frac{a(1+g)^t}{(1+i)^{2t}} + \frac{a(1+g)^{2t}}{(1+i)^{3t}} + \dots + \frac{a(1+g)^{(y-1)t}}{(1+i)^{yt}} + \dots + \frac{a(1+g)^{(n-1)t}}{(1+i)^{nt}}$$

Factoring out $\left[\frac{a}{(1+g)^t}\right]$, the series becomes:

$$\left[\frac{a}{(1+g)^t}\right] \left[\frac{1+g}{1+i}\right]^t + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1+g}{1+i}\right]^{2t} + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1+g}{1+i}\right]^{3t} + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1+g}{1+i}\right]^{yt} + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1+g}{1+i}\right]^{nt}$$

Three possible relationships exist between (i) and (g).

1. If $i > g$, then a composite discount rate (d) can be defined.

2. If $i = g$, then a direct summing of terms is possible, and the present value of the payments becomes $n \left[\frac{a}{(1+g)^t}\right]$, while the future value of the payments becomes $n \left[\frac{a}{(1+g)^t}\right] (1+i)^{nt}$.

3. If $i < g$, then a composite compound rate (c) can be defined.

The composite discount rate (d) equals $\left[\frac{(1+i)}{(1+g)} - 1\right]$.

Substituting $\left[\frac{1}{1+d}\right]$ into the above series for $\left[\frac{1+g}{1+i}\right]$, the following series results:

$$\left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+d)^t}\right] + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+d)^{2t}}\right] + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+d)^{3t}}\right] + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+d)^{yt}}\right] + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+d)^{nt}}\right]$$

The composite discount rate (d) is in annual terms. To facilitate the simplification of the above series, it is useful to define a periodic composite discount rate, $p = (1+d)^t - 1$.

Then, substituting $(1+p) = (1+d)^t$, the following series results:

$$\left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+p)}\right] + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+p)^2}\right] + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+p)^3}\right] + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+p)^y}\right] + \dots + \left[\frac{a}{(1+g)^t}\right] \left[\frac{1}{(1+p)^n}\right]$$

This series is in the same form as the series used to develop equation A, except that $\left[\frac{a}{(1+g)^t}\right]$ has replaced $\left[\frac{a}{1+g}\right]$ and (p) has replaced (d) . Therefore, the following equation (analogous to equation A) for the present value of a string of periodic payments can be derived:

$$\sum_{y=1}^n \left[\left[\frac{a}{(1+g)^t} \right] \right] = \left[\frac{a}{(1+g)^t} \right] \left[\frac{(1+p)^n - 1}{p(1+p)^n} \right]$$

Substituting, $p = (1+d)^t - 1$, and $(1+d)^t = (1+p)$

$$\sum_{y=1}^n \left[\frac{a}{(1+g)^t} \right] = \left[\frac{a}{(1+g)^t} \right] \left[\frac{(1+d)^{nt} - 1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$$

$$(I) \quad \sum_{y=1}^n \frac{a}{(1+g)^t} = a \left[\frac{(1+d)^{nt} - 1}{(1+g)^t (1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$$

$i > g$

DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting in t years)

The future value (in year nt) of a "growing" periodic payment received in the next period (in t years), and continuing every t years for a total of n periods is derived from equation I as follows:

$$\sum_{y=0}^{n-1} a(1+g)^{(n-y-1)t} (1+i)^{yt} = a(1+g)^{(n-1)t} + a(1+g)^{(n-2)t} (1+i)^t + a(1+g)^{(n-3)t} (1+i)^{2t} + \dots + a(1+g)^{(n-y-1)t} (1+i)^{yt} + a(1+g)^t (1+i)^{(n-2)t} + a(1+i)^{(n-1)t}$$

$$\sum_{y=0}^{n-1} \left[\frac{a(1+g)^{(n-1)t} (1+i)^{yt}}{(1+g)^{yt}} \right] = a \left[\frac{(1+d)^{nt} - 1}{(1+g)^t (1+d)^{nt} - 1} \right] (1+i)^{nt}$$

$$\sum_{y=0}^{n-1} a(1+g)^{(n-1)t} (1+d)^{yt} = a \left[\frac{(1+i)^{nt} [(1+d)^{nt} - 1]}{(1+g)^t [(1+i)^{nt}] [(1+d)^t - 1]} \right]$$

$$(J) \quad \sum_{y=0}^{n-1} a(1+g)^{(n-1)t} (1+d)^{yt} = a \left[\frac{(1+g)^{(n-1)t} [(1+d)^{nt} - 1]}{(1+d)^t - 1} \right]$$

i R
COMPOUNDED PERIODIC PAYMENT FACTOR
(payment starting in t years)

The composite compound rate (c) equals $\left[\frac{(1+g)}{(1+i)} - 1 \right]^{1/t}$

Substituting $(1+c)$ into the original series (p. 6 of this appendix) for $\left[\frac{1+g}{1+i} \right]$, the following series results:

$$\left[\frac{a}{(1+g)^t} \right] (1+c)^t + \left[\frac{a}{(1+g)^t} \right] (1+c)^{2t} + \left[\frac{a}{(1+g)^t} \right] (1+c)^{3t} + \dots + \left[\frac{a}{(1+g)^t} \right] (1+c)^{yt} + \dots + \left[\frac{a}{(1+g)^t} \right] (1+c)^{nt}$$

The composite compound rate (c) is in annual terms. To facilitate the simplification of the above series, it is useful to define a periodic composite compound rate, $p = (1+c)^t - 1$.

Then, substituting $(1+p) = (1+c)^t$, the following series results:

$$\left[\frac{a}{(1+g)^t} \right] (1+p) + \left[\frac{a}{(1+g)^t} \right] (1+p)^2 + \left[\frac{a}{(1+g)^t} \right] (1+p)^3 + \dots + \left[\frac{a}{(1+g)^t} \right] (1+p)^y + \dots + \left[\frac{a}{(1+g)^t} \right] (1+p)^n$$

This series is in the same form as the series used to develop equation C, except that $\left[\frac{a}{(1+g)^t} \right]$ has replaced $\left[\frac{a}{1+g} \right]$ and (p) has replaced (c) . Therefore, the following equation (analogous to equation C) for the future value of a string of periodic payments can be derived:

$$\sum_{y=1}^n \left[\frac{a}{(1+g)^t} \right] (1+p)^y = \frac{a}{(1+g)^t} \left[\frac{(1+p) [(1+p)^n - 1]}{p} \right]$$

Substituting, $p = (1+c)^t - 1$, and $(1+c)^t = (1+p)$

$$\begin{aligned} \sum_{y=1}^n \left[\frac{a}{(1+g)^t} \right] (1+c)^{yt} &= a \left[\frac{(1+c)^t [(1+c)^{nt} - 1]}{(1+g)^t [(1+c)^t - 1]} \right] \\ &= a \left[\frac{(1+g)^t}{(1+i)^t} \left[\frac{(1+c)^{nt} - 1}{(1+c)^t - 1} \right] \right] \end{aligned}$$

1/ See footnote 1, page 2 of this appendix.

$$(K) \sum_{y=1}^n \left[\frac{a}{(1+g)^t} \right] (1+i)^{yt} = a \left[\frac{(1+g)^{nt} - 1}{(1+i)^t [(1+g)^t - 1]} \right]$$

$i < g$
DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting in t years)

The future value form of equation K is derived in the manner of equation J, using the same series, repeated below;

$$\sum_{y=0}^{n-1} a(1+g)^{(n-y-1)t} (1+i)^{yt} = a(1+g)^{(n-1)t} + a(1+g)^{(n-2)t} (1+i)^t + a(1+g)^{(n-3)t} (1+i)^{2t} + \dots + a(1+g)^{(n-y-1)t} (1+i)^{yt} + \dots + a(1+g)^t (1+i)^{(n-2)t} + a(1+i)^{(n-1)t}$$

$$\sum_{y=0}^{n-1} \left[\frac{a(1+g)^{(n-1)t} (1+i)^{yt}}{(1+g)^{yt}} \right] = a \left[\frac{(1+g)^{nt} - 1}{(1+i)^t [(1+g)^t - 1]} \right] (1+i)^{nt}$$

$$(L) \sum_{y=0}^{n-1} \left[\frac{a(1+g)^{(n-1)t}}{(1+g)^{yt}} \right] = a \left[\frac{(1+i)^{(n-1)t} [(1+g)^{nt} - 1]}{(1+i)^t - 1} \right]$$

$i < g$
COMPOUNDED PERIODIC PAYMENT FACTOR
(payment starting in t years)

Determination of present value factors and future value factors for periodic payments beginning "this year"

The usual case for a series representing the present value of periodic payment beginning this year and continuing every (t) years for (n) more periods is:^{1/}

$$\sum_{y=0}^n \frac{a}{(1+i)^{yt}} = a + \frac{a}{(1+i)^t} + \frac{a}{(1+i)^{2t}} + \dots + \frac{a}{(1+i)^{yt}} + \dots + \frac{a}{(1+i)^{nt}}$$

where, a = periodic payment beginning this year and continuing every t years for n more periods.

t = time interval between periods

n = number of periodic payments after first payment (there are $n+1$ payments and nt equals the number of years until the last payment)

i = rate of annual interest (discount)

y = any given period (yt equals any given year in which a payment occurs)

However, this again only represents the special case when (a) remains constant. When (a) increases at a rate (g) each year, the following sequence results:^{2/}

$$a, a(1+g)^t, a(1+g)^{2t}, \dots, a(1+g)^{yt}, \dots, a(1+g)^{nt}$$

The present value of all $(n+1)$ payments is represented by the following series:

$$a + a \left[\frac{1+g}{1+i} \right]^t + a \left[\frac{1+g}{1+i} \right]^{2t} + \dots + a \left[\frac{1+g}{1+i} \right]^{yt} + \dots + a \left[\frac{1+g}{1+i} \right]^{nt}$$

As before, three possible relationships exist between (i) and (g)

1. If $i > g$, then a composite discount rate (d) can be defined.

2. If $i = g$, then a direct summing of terms is possible, and the present value of the payments becomes $a(n+1)$, while the future value of the payments becomes $a(n+1)(1+i)^{nt}$.

3. If $i < g$, then a composite compound rate (c) can be defined.

1/ See Appendix 1, page 4.

2/ The rate (g) could also represent an annual decrease in (a) . In that case (g) would be negative. If two or more growth rates affected (a) , (g) would be a composite of all growth rates.

Again, the composite discount rate (d) equals: $\left[\frac{(1+i)}{(1+g)} - 1 \right]$.

Substituting $\left[\frac{i}{(1+d)} \right]$ into the above series for $\left[\frac{1+g}{1+i} \right]$, the following series results:

$$a + \frac{a}{(1+d)^t} + \frac{a}{(1+d)^{2t}} + \dots + \frac{a}{(1+d)^{yt}} + \dots + \frac{a}{(1+d)^{nt}}$$

As before the composite discount rate (d) is in annual terms. To facilitate the simplification of the above series, it is useful to define a periodic composite discount rate, $p = (1+d)^t - 1$.

Then, substituting $(1+p) = (1+d)^t$, the following series results:

$$a + \frac{1}{(1+p)} + \frac{a}{(1+p)^2} + \dots + \frac{a}{(1+p)^y} + \dots + \frac{a}{(1+p)^n}$$

This series is in the same form as the series used to develop equation E, except that (p) has replaced (d). Therefore, the following equation (analogous to equation E) for the present value of a string of periodic payments can be derived:

$$\sum_{y=0}^n \frac{a}{(1+p)^y} = a \left[\frac{(1+p)^{n+1} - 1}{p(1+p)^n} \right]$$

Substituting, $p = (1+d)^t - 1$, and $(1+d)^t = (1+p)$

$$(M) \quad \sum_{y=0}^n \frac{a}{(1+d)^{yt}} = a \left[\frac{(1+d)^{(n+1)t} - 1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right] \quad \begin{matrix} i > g \\ \text{DISCOUNTED PERIODIC PAYMENT FACTOR} \\ (\text{payment starting "this year"}) \end{matrix}$$

The future value equation is derived from equation M as follows:

$$\sum_{y=0}^n a (1+g)^{(n-y)t} (1+i)^{yt} = a (1+g)^{nt} + a (1+g)^{(n-1)t} (1+i)^t + a (1+g)^{(n-2)t} (1+i)^{2t} + \dots + a (1+g)^{(n-y)t} (1+i)^{yt} + \dots + a (1+g)^t (1+i)^{(n-1)t} + a (1+i)^{nt}$$

$$\sum_{y=0}^n \frac{a (1+g)^{nt} (1+i)^{yt}}{(1+g)^{yt}} = a \left[\frac{(1+d)^{(n+1)t} - 1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right] (1+i)^{nt}$$

$$\sum_{y=0}^n a (1+g)^{nt} (1+d)^{yt} = a \left[\frac{(1+i)^{nt} \left[(1+d)^{(n+1)t} - 1 \right]}{\left[(1+i)^{nt} \right] \left[(1+d)^t - 1 \right]} \right]$$

$$(N) \quad \sum_{y=0}^n a (1+g)^{nt} (1+d)^{yt} = a \left[\frac{(1+i)^{nt} \left[(1+d)^{(n+1)t} - 1 \right]}{(1+d)^t - 1} \right] \quad \begin{matrix} i > g \\ \text{COMPOUNDED PERIODIC PAYMENT FACTOR} \\ (\text{payment starting "this year"}) \end{matrix}$$

The composite compound rate (c) again equals $\left[\frac{(1+g)}{(1+i)} - 1 \right] \cdot \frac{1}{t}$

1/ See footnote 1, p 2 of this appendix.

Substituting $(1+c)$ into the original series (p 8 of this appendix) for $\left[\frac{1+g}{1+i} \right]$, the following series results:

$$a + a(1+c)^t + a(1+c)^{2t} + \dots + a(1+c)^yt + \dots + a(1+c)^{nt}$$

As before, the composite compound rate (c) is in annual terms. To facilitate the simplification of the above series, it is useful to define a periodic composite compound rate, $p = (1+c)^t - 1$.

Then, substituting $(1+p) = (1+c)^t$, the following series results:

$$a + a(1+p) + a(1+p)^2 + \dots + a(1+p)^y + \dots + a(1+p)^n$$

This series is in the same form as the series used to develop equation G, except that (p) has replaced (c) . Therefore, the following equation (analogous to equation G) for the present value of a string of periodic payments beginning this year can be derived:

$$\sum_{y=0}^n a(1+p)^y = a \left[\frac{(1+p)^{n+1} - 1}{p} \right]$$

Substituting, $p = (1+c)^t - 1$, and $(1+c)^t = (1+p)$

$$(0) \sum_{y=0}^n a(1+c)^{yt} = a \left[\frac{(1+c)^{(n+1)t} - 1}{(1+c)^t - 1} \right]$$

$i < g$
DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting "this year")

The future value form of equation 0 is derived in the manner of equation N, using the same series, repeated below:

$$\sum_{y=0}^n a(1+g)^{(n-y)t} (1+i)^{yt} = a(1+g)^{nt} + a(1+g)^{(n-1)t} (1+i)^t + a(1+g)^{(n-2)t} (1+i)^{2t} + \dots + a(1+g)^{(n-y)t} (1+i)^{yt}$$

$$\dots + a(1+g)^t (1+i)^{(n-1)t} + a(1+i)^{nt}$$

$$\sum_{y=0}^n a(1+g)^{(n-y)t} (1+i)^{yt} = a(1+g)^{nt} + a(1+g)^{(n-1)t} (1+i)^t + a(1+g)^{(n-2)t} (1+i)^{2t} + \dots + a(1+g)^{(n-y)t}$$

$$(1+i)^{yt} + \dots + a(1+g)^t (1+i)^{(n-1)t} + a(1+i)^{nt}$$

$$\sum_{y=0}^n \left[\frac{a(1+g)^{nt} (1+i)^{yt}}{(1+g)^{yt}} \right] = a \left[\frac{(1+c)^{(n+1)t} - 1}{(1+c)^t - 1} \right] (1+i)^{nt}$$

$$(P) \sum_{y=0}^n \left[\frac{a(1+g)^{nt}}{(1+c)^{yt}} \right] = a \left[\frac{(1+i)^{nt} \left[\frac{(1+c)^{(n+1)t} - 1}{(1+c)^t - 1} \right]}{(1+c)^t - 1} \right]$$

$i < g$
COMPOUNDED PERIODIC PAYMENT FACTOR
(payment starting "this year")

Periodic capital recovery factors and sinking fund factors

Theoretically, periodic capital recovery factors and periodic sinking fund factors are possible (see Appendix 1, page 5). However, neither factor generally considers growth rates (see page 5 of this appendix). If some application of periodic capital recovery factors or sinking fund factors (which include an annual growth rate) exists, the present value and future value formulas for periodic payments (which include an annual growth rate) can be inverted and used in the manner described in Appendix 1.

Determination of "infinite" factors

When annual or periodic payments (which include an annual growth rate $-g$) continue for an infinite period (or for a sufficiently long finite period such that the "next" payment has no measurable present value) some of the equations for present values of such payments become much simplified. Only cases where $i < g$ can be simplified, since when $i > g$ the present values of successive payments do not decrease. Four equations described in this appendix can be simplified, equations A, E, I, and M.

$$(A) \sum_{y=1}^n \frac{\left[\frac{a}{1+g} \right]}{(1+d)^y} = a \left[\frac{(1+d)^n - 1}{d(1+d)^n (1+g)} \right] \rightarrow \left[\frac{1}{d(1+g)} - \frac{1}{d(1+d)^n (1+g)} \right]$$

when $n \rightarrow \infty$, the second term $\left[\frac{1}{d(1+d)^n (1+g)} \right]$ approaches zero, leaving

$i > g$: INFINITE

DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "next year")

$$\left[\frac{1}{d(1+g)} \right]$$

Therefore:

$$(Q) \sum_{y=1}^{n=\infty} \frac{\left[\frac{a}{1+g} \right]}{(1+d)^y} = a \left[\frac{1}{d(1+g)} \right]$$

$i > g$: INFINITE

DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "next year")

$$(E) \sum_{y=0}^n \frac{a}{(1+d)^y} = a \left[\frac{(1+d)^{n+1} - 1}{d(1+d)^n} \right] = a \left[\frac{1+d}{d} - \frac{1}{d(1+d)^n} \right]$$

$i > g$: FINITE

DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "this year")

When $n \rightarrow \infty$, the second term $\left[\frac{1}{d(1+d)^n} \right]$ approaches zero, leaving $\left[\frac{1+d}{d} \right]$

Therefore:

$$(R) \sum_{y=0}^{n=\infty} \frac{a}{(1+d)^y} = a \left[\frac{1+d}{d} \right]$$

$i > g$: INFINITE

DISCOUNTED ANNUAL PAYMENT FACTOR
(payment begins "this year")

$$(I) \sum_{y=1}^n \frac{\left[\frac{a}{(1+g)^t} \right]}{(1+d)^{yt}} = a \left[\frac{(1+d)^{nt} - 1}{(1+g)^t (1+d)^{nt} \left[(1+d)^t - 1 \right]} \right] = a \left[\frac{1}{(1+g)^t \left[(1+d)^t - 1 \right]} - \frac{1}{(1+g)^t (1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$$

$i > g$: FINITE

DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting in t years)

When $n \rightarrow \infty$, the second term $\left[\frac{1}{(1+g)^t (1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$ approaches zero, leaving $\frac{1}{(1+g)^t \left[(1+d)^t - 1 \right]}$

Therefore:

$$(S) \sum_{y=1}^{n=\infty} \frac{\left[\frac{a}{(1+g)^t} \right]}{(1+d)^{yt}} = a \left[\frac{1}{(1+g)^t \left[(1+d)^t - 1 \right]} \right]$$

$i > g$: INFINITE

DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting in t years)

$$(M) \sum_{y=0}^n \frac{a}{(1+d)^{yt}} = a \left[\frac{(1+d)^{(n+1)t} - 1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right] = a \left[\frac{(1+d)^t}{(1+d)^t - 1} - \frac{1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$$

$i > g$: FINITE

DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting "this year")

When $n \rightarrow \infty$, the second term $\left[\frac{1}{(1+d)^{nt} \left[(1+d)^t - 1 \right]} \right]$ approaches zero, leaving

$$\left[\frac{(1+d)^t}{(1+d)^t - 1} \right]$$

Therefore:

$$(T) \sum_{y=0}^{n=\infty} \frac{a}{(1+d)^{yt}} = a \left[\frac{(1+d)^t}{(1+d)^t - 1} \right]$$

$i > g$: INFINITE

DISCOUNTED PERIODIC PAYMENT FACTOR
(payment starting "this year")

Appendix 3

Application of Electronic Calculators to Solutions of Discounting Problems

Several types of electronic calculators can automatically calculate the present value of a series of annual or periodic payments. Some electronic calculators also have the option of selecting either the end of year (column 1 of Table 2) factors or the beginning of year (column 3 of Table 3) factors.^{1/} For those calculators which only specify the end of year factors, one can calculate the beginning of year factors by adding in the value of the first payment. ^{2/} For example, the case illustrated in Table 4 applied the factor for the present value of an annual payment beginning immediately. The discounted value of net benefits for years 7-19 (W43.9 annually) was determined using a calculator to calculate the discounted value of a sequence of annual payments of W43.9 which began in year 8 and continued through year 19. The discounted value of these 12 annual payments (at a 10 percent discount rate) was automatically calculated to be W299.1. The value of net benefits for year seven was added (W299.1) + (W43.9) to give a total discounted value (in year 7) of W343.0.

To derive discounted and compounded values of periodic payments using electronic calculators, one first needs to calculate a periodic discount rate (p) equal to: $((1+i)^t - 1)$, where (i) equals the annual discount rate and (t) equals the period between payments. Then the periodic payments can be treated as annual payments on the calculator, using (p) instead of (i). To calculate beginning of period and end of period payments, the same steps need to be followed as were described above for annual payments.

The use of a periodic discount rate can be illustrated by using the periodic net benefit (of W90.2) from Table 7. The periodic discount rate equals 21 percent $((1.10)^2 - 1)$, and 6 periodic payments occur after year 6. The discounted value of the 6 payments (using the 21 percent discount rate) equals W292.7. Adding the value (in year 6) of the first payment (W292.7 + W90.2), the total discounted value equals W382.9, as shown in Table 7.

A few of the annual payment formulas in Table 10 closely resemble their "non-growth" counterparts in Table 2. By substituting (d) or (c) for (i), and in some cases by further multiplying by an additional factor, electronic calculators with financial functions can be used to quickly calculate discounted or compounded values. However, for most of the formulas in Table 10, the adjustments necessary to "fit" the formulas into the electronic calculator's format are more time consuming than directly calculating the formula through multiplication of its components.

^{1/} Table numbers refer to tables in the text.

^{2/} The "end of a given year" is equal to the "beginning of the following year" in this terminology, i.e., on a calendar year basis, 31 Dec., 11:59 p.m., 1976 equals 1 Jan., 00:01 a.m., 1977.

Appendix 4

Calculation of Net Present Worth (NPW) in Table 3

The calculation of the net present worth (NPW) for the Korea cash flow (Table 1) is demonstrated in Table 3.¹⁷ Eight single years or annual series of years which have different net benefits (costs) are identified in the eight rows of Table 3. Column 1 of Table 3 lists each year or annual series of years, and column 2 shows the net benefits and costs from Table 1. These two columns contain all of the information found in row 8 of Table 1. Columns 3 and 4 of Table 3 identify the initial years of discount and the discounted values, respectively, for the two series of annual payments (rows 2 and 7). Since Table 3 illustrates the use of the "end of year" annual payment formula, each initial year of discount equals the year prior to the start of the annual series. The discounted values in column 4 are determined by using the "end of year" annual payment formula (from row 1, column 1 of Table 2) and a discount rate of 10 percent. Column 5 of Table 3 indicates the present value (year 0) of each single payment and series of annual payments. The present values of the 6 single payments in Table 3 (rows 1, 3, 4, 5, 6 and 8) equal the values in column 2 discounted at 10 percent for the number of years indicated in column 1. The present values of the 2 series of annual payments (rows 2 and 7) equal the values in column 4 discounted at 10 percent for the number of years indicated in column 3. The final step is to add all of the 8 present values in column 5 to get the net present worth (NPW), equal to W170.0.

¹⁷ Tables referred to in this appendix are text tables.