A MULTI-CRITERIA FRAMEWORK FOR APPRAISAL OF RURAL ROADS IN DEVELOPING COUNTRIES

by

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ABSTRACT

It has been widely recognized that the sole use of economic criterion in the appraisal of development projects in developing countries has led to substantial national aggregate economic growth but inequality and poverty have not been reduced nor has sufficient productive employment been provided. The sufferings of the poorest of the poor particularly in the rural areas necessitates urgent action for alleviation.

Transportation is recognized as a necessary (though insufficient in itself) prerequisite for development. The future emphasis on rural development will thus entail substantial investment in rural roads.

The above commentary thus points out the necessity to incorporate socio-economic criteria to the traditional economic criterion in the appraisal of rural road projects. Specifically, this, then, is the purpose of this thesis; the development of a multi-criteria appraisal framework which will enable the multiple socio-economic objectives of the rural development effort to be accounted for in the appraisal of rural transport projects.

The formulation of the framework involves the identification of, firstly, the relevant criteria, secondly, the ways in which the measures of these criteria might be collected and lastly, the ways in which the measures of the criteria might be combined to form an explicit value structure as a basis for decision making. Following this, a case study is structured to illustrate the implementation of the framework.

Name and Title of Thesis Supervisor: Fred Moavenzadeh, Professor of Civil Engineering.

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CHAPTER I; INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

Despite a good rate of national growth in many developing countries in the past decade, rural poverty is increasing and the number of people living on the margin of existence is rising. These "marginal people" are not integrated into the mainstream of national life, they barely participate in the market economy, and they have little hope for the future. It is estimated that 85% of the 750 million poor in the developing countries are in absolute poverty*. Further, it is estimated that 80% of these 750 million people live in the rural areas. These are indeed startling figures, and it seems imperative that some immediate action be taken to correct the current situation.

Lending agencies as a whole and the World Bank in particular have recently begun to show a marked change in the type of projects being considered for implementation within developing countries. In the past it was considered judicious to allocate funds to those projects with the greatest return to capital. Using traditional methods of project evaluation for the transport sector, namely savings in user costs, investments tended to be biased toward "high-growth", modern sectors of economy, such as: (1) the upgrading of already heavily traveled elements of the primary or secondary system, and (2) new connections between large

*From World Bank, "Rural Development Sector Policy Paper," February 1975, wherein absolute poverty arbitrarily designates those with a per capita income of less than US $50, and poor arbitrarily designates those with a per capita income of less then one-third the national average.

urban centers or other massive attraction/generation centers such as ports. This policy can be considered to be successful in that, in the past decade, the average rate of increase in the gross national product of the less developed countries has been about 5% per annum (this average conceals wide ranges of variations).

At the same time, however, discontent is occurring within the developing countries since rural poverty is increasing in spite of national growth. With the expected increase in attention on the development of rural areas, there will be a substantial increase in investment in transportation, as it is widely recognized that transportation is necessary - though insufficient in itself - to generate development. The investments may be expected to be increasingly geared toward the construction of feeder roads to open up more lands, and, according to Odier (1976), toward "the thorough integration of [rural] populations into the national economic, social, and political channels by freeing these populations from isolation and by connecting them to the network's frame through transport facilities which provide them with easy communications between each other and with the country's sectors of activity from which they had been kept apart."

1.2 RURAL DEVELOPMENT

1.2.1 Objectives and Strategy

It can be, and has been, asserted that through rural development many of the sufferings of the large number of rural poor may be alleviated.

Perhaps a more important issue is the survival of the rapidly increasing rural population, which hinges on the successful mobilization of the abundant resources of rural labor, in combination with the existing more limited resources of land, capital, and technology, together with the inputs of additional capital and appropriate technology from abroad or from within the individual country.

The basic objectives* of rural development might be stated as including:

(1) the improvement of productivity;

(2) the generation of employment and corresponding higher incomes for target groups; and

(3) provision of minimum acceptable levels of food, shelter, education, and health.

Thus it is the mobilization of the available factors of production in the rural areas that is important if socio-economic development is to occur. The tasks entailed in this are enormous due to the tremendous magnitude of the problem. Correspondingly, "experience indicates that a strong commitment to rural development at the national policy level is necessary if the impact is to be effective and broad-based."* The fuller development of the existing resources, the building of infrastructure such as roads and irrigation, the introduction of new improved technology for existing agriculture or new crops and the creation of new types of institutions and organization are but some of the tasks lying ahead.

*World Bank, "Rural Development Sector Policy Paper," February 1975.

These ideas are widely recognized and well known, but the development resulting from past efforts has primarily brought about large aggregate growth due to the emphasis on economic growth. The thrust for the future, to ensure that the majority of the rural poor will benefit from the rural development efforts, should, therefore, strive to aim for growth but with greater emphasis on distribution. A change in the pattern of development is thus advocated - a pattern that is more concerned with the distribution aspect relative to the former patterns of growth.

1.2.2 Role of Transportation*

In beginning to discuss the role of transportation in the process of rural development, one faces a problem in trying to generalize the situation. The nature and degree of impacts depend very much, on the one hand, on the existing social and economic environments of the particular area and, on the other hand, on the kinds of economic, social, and institutional changes imposed on the area by the various policy and investment decisions.

A recent study by Hofmeier (1973) illustrates certain of these non-generality problems as well as the role of transportation in rural development. He initially attempted to utilize time series data for Tanzania to study the effects of the provision of road transport. The difficulties he faced were due to the lack of quantitative data for agricultural production over time; most available data was too aggregated to permit an adequate analysis of the long-term effects or otherwise of particular

*When the word transportation is used, it is meant to refer to roads and road transportation. The relevance of different modes; railways, air transport, etc., will not be discussed.

sections of roads. The limited data that was available for agricultural production for certain years could not be meaningfully used because there were very wide fluctuations in weather conditions which affected agricultural production. He finally settled on a comparative analysis of different areas similar in their basic physical structure but with differing degrees of accessibility. This was performed for a particular time period.

Detailed data on the structure of production and income in three villages in the Usambara Mountains of the Tanga region in Tanzania were available for the years 1965-1966. The physical characteristics of these three villages (Soni, Bumbuli, and Mulungui) were identical; the only significant difference was in the degree of accessibility. Mulungui has no linkage to the existing road network and is a half hour's walk from Bumbuli, which is served by a dry-weather road (impassable when there are heavy rains) linking it to Soni. Soni, in turn, is served by a relatively good all-weather road which connects it to the nearby market towns.

The data presented in Table 1-1 shows some interesting observations concerning the pattern of the productive structure, as influenced by the different degree of accessibility. Subsistence agriculture has decreased in importance in Soni, an increasing percentage of the demand being met with market purchases. Further, some of the farmers in Soni are able to employ wage laborers for the specialized cultivation of vegetables which can be sold in the nearby towns. The value of subsistence agriculture

TABLE 1-1
RETURNS AND INCOME FROM AGRICULTURE IN
THREE SELECTED VILLAGES OF
TANGA REGION, TANZANIA 1965/66
(in TShs per household per year)

	Soni	Bumbuli	Mulungui
Sale of cash crops	1640	328	40
Value of subsistence production	917	1040	580
Returns from cattle	174	39	73
Gross farm income	2731	1407	693
-Production inputs	94	59	41
-Wages	96	56	---
Family income from agriculture	2541	1292	652
Non-agricultural income	315	645	183
Total family income	2856	1937	835
of this monetary income (net)	1824	878	202
Gross return in TShs per acre	1020	515	420
Degree of commercialization of agriculture (% share of cash crop sales out of gross income)	60	15	4

Source: R. Hofmeier, Transport and Economic Development in Tanzania (page 264).

in Bumbuli is higher than in Soni, and the populace of Bumbuli has to rely more on extra-agricultural activities for further incomes. The situation in Mulungui is a very inactive one, although it is only a half hour walk from Bumbuli. These inhabitants are generally less active and more resigned to a low standard of living and little development.

Thus in this special comparative case study, Hofmeier has demonstrated in an isolated way how differing transportation accesibility affects the development of particular rural areas. In general, it is widely recognized that transportation is a necessary ingredient of rural development. However, transportation by itself will not, in general, be sufficient to guarantee development. There are various complementary investments that are also needed, for example, technical assistance and other extension help are very necessary to speed up the improvement of the productivity of the farmers. Roads in this context are the means for the provision of the necessary inputs. We cannot expect extension workers who are probably from some more developed areas to be willing to stay in isolated areas for the long periods of time needed to impart the help and assistance to the farmers. Thus although the opening of accessibility to the areas of interest is a prerequisite, it is, in general, insufficient for a rapid increase in productivity and standard of living for the rural poor.

1.2.3 Complementary Investment Needs

To reinforce the concept of the need for complementary investments, an illustration of the reasons Sen (1974) sees for the weaknesses of the village roads constructed under the Community Development Program in India, may help to clarify the picture. These reasons were:

(1) the roads were conceived hastily with inadequate design and layout;

(2) they were not treated as a productive potential, but rather as a welfare package;

(3) they were not regarded as a means for raising and marketing farm produce, but rather as a rural amenity;

(4) they were in general not very well linked to the markets;

(5) there was no complementary use of productive inputs;

(6) a cheap food policy existed that acted to depress prices, and correspondingly there was no incentive to increase agricultural production; and

(7) no complementary storage and warehouse facilities were advocated.

It appears in this context then, that feeder road projects cannot be treated by itself but must be considered with all the necessary complementary activities. Thus in this study when we refer to feeder road projects, these complementary activities* are implicitly considered.

1.3 THE PROJECT CYCLE

The cycle of any development project consists of four basic stages of activity, each following the other in a continuous fashion.

*See Section 4.1 for a more detailed description.

The activities basically include first, the identification of the project, second, the preparation for appraisal, third, the appraisal of the project, and fourth, if the the project is successfully approved, the implementation and monitoring of the project to ensure that it meets the development objectives it was designed to achieve. The cycle of activities so described parallels the basic framework used by the World Bank in the planning and implementation of development projects. (Baum, 1970).

For the purposes of this study, the project cycle might be condensed into three broad categories of activity, consisting of:

(a) a design problem,

(b) an appraisal problem, and

(c) an implementation problem.

The design problem is taken to consist of the identification and preparation stages, while the appraisal problem is the appraisal stage, and the implementation problem is the implementation and monitoring stage.

It is recognized that each of these three problems is an important category by itself and needs separate treatment and emphasis since each has different characteristics and operational differences. Ideally, the analysts involved with the design problem and those involved with the appraisal problem should be different in the interests of objectivity. The emphasis of this study will be on the appraisal problem with only a cursory treatment of the other two, as it is beyond the scope of this study to cover all three problems in a comprehensive way.

For a brief treatment of the design and implementation problems, the following recurring weaknesses of past and ongoing rural development projects might be noted.* These are:

(1) Projects are often designed using unnecessary capital (equipment) - intensive techniques resulting in the unskilled labor's share of total expenditures being below what might ideally be achieved.

(2) The absence of adequate management and supervision of the projects can lead to inefficiencies and escalating costs coupled with the creation of low morale.

(3) The agricultural cycle normally has certain peak periods when almost all the available labor is fully utilized; projects must thus be designed with great care to ensure that the labor demands of the project do not clash with this critical peak period of agricultural labor demand.

(4) The payment to the labor in kind can often lead to inefficiencies if the commodities do not meet their perceived needs and are resold by the peasants at a reduced price.

(5) It is usually desirable to have the affected populace take some initiative and participate in the local decision-making process while maintaining adequate central control; in practice, this ideal is difficult to achieve.

(6) The presence of influential interest groups often results in manipulation of the project to their benefit at the expense of the poor majority.

Looking toward the appraisal problem, the use of relevant multi-criteria in the appraisal of rural road projects is to ensure that their contribution to the multi-objectives, which the rural development program

*World Bank, "Rural Development Sector Policy Paper", February 1975 (Page 51).

was designed to achieve, will be maximized. The structuring of an adequate appraisal framework is thus important as the limited funds available in developing countries should be used only for the "best" projects that can be selected. "Best" has traditionally been taken to be attainment of the purely economic objective, but this has been recognized as inadequate in view of the need to account for the attainment of additional objectives such as the distribution of economic benefits to the target poor, the creation of employment, and the accessibility to social services.

1.4 PURPOSE AND SCOPE OF THE STUDY

In summary it can be said that even though transportation is insufficient in itself to guarantee development, it is in general a necessary prerequisite. The question of how much resources should be allocated to transportation is an issue that is not addressed here, but rather is left to the existing decision process. The question that is handled is, once the budget for a specific rural roads (rural development) program has been allocated, how the projects can be appraised and selected so as to maximize their achievement of the multi-objectives of the rural development effort.

Conducting a comprehensive and critical review of the project evaluation literature, specifically that related to techniques applicable to rural road appraisals in developing countries or those applicable in developing countries in general, is the first task. The results of this are presented in Chapter 2. In Chapter 3, a multi-criteria appraisal framework is formulated, having the capability to account for the attainment of the multi-objectives of rural development in the appraisal of rural road projects. An illustrative case study is structured in Chapter 4 to demonstrate the implementation of the multi-criteria appraisal framework. Finally Chapter 5 presents the conclusions of the study and some recommendations for future research.

CHAPTER 2: REVIEW OF THE LITERATURE

2.1 SOCIO-ECONOMIC ASPECTS OF RURAL DEVELOPMENT.

It is readily accepted conceptually, though not so readily in practice, that development is a multi-dimensional issue. It has been the practice to subsume development in general under the heading of economic development in particular. However important the economic dimension of development, it is dangerous to use it as a proxy for development. The objective becomes that of linking the various dimensions of development along with appropriate metrics into a feasible plan. It is necessary then for project appraisal to include the investigation of the components of levels of living, such as education, health, and housing, both as 'outcome of expenditure' and as 'inputs' in the economic process, as well as including components relating to the capacity of the system to carry out the policy measures necessary for economic development. These components are institutional and non-economic factors which lie outside the traditional subset of economic variables, where indicators are less clearly defined, and the links with economic variables less clearly specified. Integrating the different dimensions of development involves: defining major areas of development policy (such as equity or distribution to the rural poor, or technological and institutional change); defining measures or operational indicators for these different dimensions; tracing the links between the areas of development policy.

The relevant considerations consist of impacts related to the socio-economic welfare of the rural community as a consequence of the development project. The alleviation of the sufferings of the poorest among the rural population is of primary importance. This entails the necessity for benefits to reach these target populations and, hence, the distribution of project beneficiaries has to be accounted for as the consideration of who the beneficiaries of public investments are and who they should be has become a critical issue. Carnemark et al (1976) recognizes the importance of the distribution issue in appraising feeder road projects but deals with it only in an indirect manner by suggesting that if complementary investments which generate incentives for the smaller farmers are included, the distribution of project beneficiaries may be improved.

The point to be emphasized is that a framework for the appraisal of feeder roads must contain a mechanism whereby the distribution of project benefits can be accounted for. Conceptually, this idea appears quite straightforward but, unfortunately, in practice, various difficult problems arise, for example, the prediction of the small farmers' share of the induced agricultural production is in practice hard to make. If in a specific instance where the majority of the land in the zone of influence of the proposed feeder road is owned by a few big landlords then the trickle down benefits of induced agricultural production to the small landless farmers will be negligible.

The creation of employment as a direct consequence of the road, such as in using labor-intensive as opposed to capital-intensive construction strategy is a very important consideration for using underutilized farm labor during the "off season" of agriculture.

The introduction of new technology like fertilizers, new seed varieties, etc., will contribute to improved productivity of the factors of production. To complement this, the degree and availablity of agricultural extension services will also determine the kinds of productivity gains that will be achieved.

From another angle the availability of social services, such as medical and health services and advice, proper nutritional care for the young and education facilities, will determine to a large extent the improvement of social and economic welfare of the rural populace. These are also important determinants to ensure the continued self-sustaining momentum of the rural development efforts.

The success of these efforts will stimulate growth in production and growth in consumer demand resulting in the generation and expansion of commercial activities. It is thus important that socio-economic aspects be taken into account in the evaluation of feeder road projects, for these important considerations of interest in rural development and their inclusion will impart a more valid basis for the appraisal of these projects.

On the other hand however, a note of caution is necessary to ensure that a correct balance is realized in the analysis of all these concerns in order that the methodology will not be self-defeating by being too complex and/or requires too much detailed data that is impossible or too expensive to obtain.

With the discussion of the above considerations in mind, we now focus on the strictly economic analysis of projects and analyzed how and whether social objectives are being integrated within this analysis.

2.2 APPRAISAL METHODOLOGIES

2.2.1 Single Objective Analysis

2.2.1.1 Benefits = User Savings

Traditionally, transport project planners have analyzed various alternatives and employed project selection criteria based on the amount of vehicle user savings generated by any transport improvement. Benefits are accounted using an implicit consumer surplus approach:

$$\text{BENEFITS} = \Delta P T_0 \text{ (due to normal traffic)}$$

$$+ 1/2\ \Delta P \Delta T \text{ (due to generated traffic)}$$

where $\Delta P = P_0 - P_1$ and $\Delta T = T_1 - T_0$ (see Figure 2-1)

This approach involves the estimation of vehicle trips or alternatively predicting the amount of generated traffic due to a particular improvement. Costs are analyzed on a before and after basis over the anticipated life of the project and these costs are compared in typically any of three ways: the net present value approach (NPV); the benefit-cost ratio approach (B/C); or the internal rate of-return approach (IRR). Each justification approach has its deficiencies, and the B/C method in particular is gathering more discredit due to the subjective element introduced in defining benefits versus costs. Although the B/C approach is easily discredited, its simplicity of use and history of use continue to make it a widely utilized tool in project evaluation practice.

The mathematical interpretation of each is:

$$NPV = \sum_{t=1}^{N} [B_t - C_t] / [1 + i]^t$$

$$B/C = [\sum_{t=1}^{N} B_t/(1+ i)^t] / [\sum_{t=1}^{N} C_t/(1 + i)^t]$$

IRR = that i at which

$$\sum_{t=1}^{N} B_t/ (1 + i)^t] = [\sum_{t=1}^{N} C_t / (1 + i)^t]$$

where: B_t = benefits in year t

C_t = costs in year t

i = social rate of discount

N = total number of periods

Any alternative project such that NPV<0; B/C <1.0 or IRR $<i^*$ (minimum acceptable rate of return) can be deleted from consideration. Perhaps an important issue of the above evaluation method (and subsequent evaluation methods) is the actual accounting of costs and benefits. Due to various market imperfections or distortions, the actual market price of say gasoline may not represent the true opportunity cost of this resource. Since in our investment decisions we are concerned only with the opportunity cost to the country or region affected, we need devise what are called "accounting prices" or "shadow prices". These methods of pricing really took affect in the mid 60's, and have come also to be known as "efficiency prices", those prices which approximate the opportunity cost of the resources used, but do not consider distributional aspects of the benefits-cost stream.

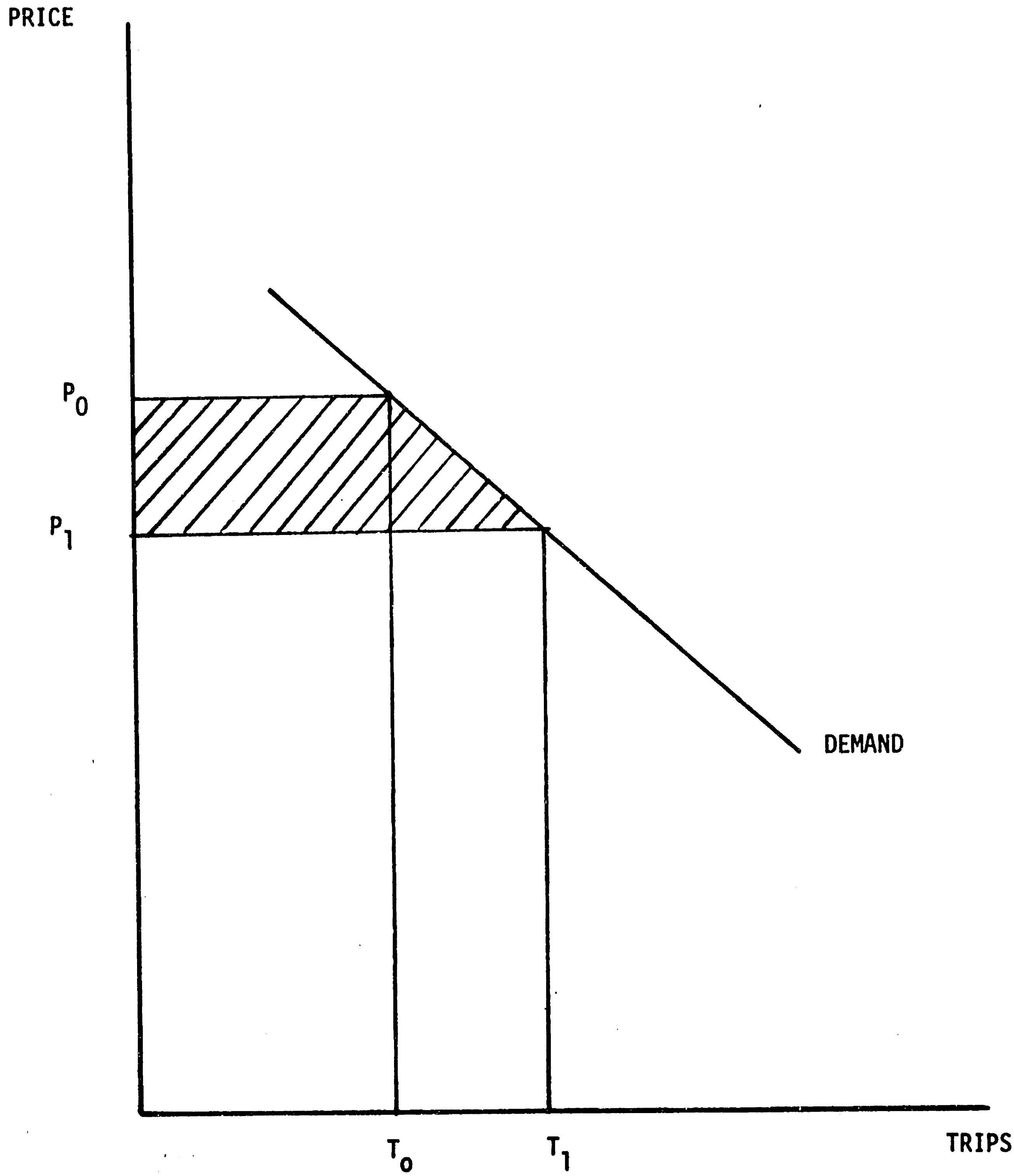

FIGURE 2-1 BENEFITS = USER SAVINGS

The problem with this traditional approach to transport project evaluation in regards to rural areas is its dependency on sufficient existing and generated vehicle trips to justify a transport improvement.

A sufficient number of vehicle trips may not presently exist, and as was pointed out in the introduction, continued use of the above evaluation method has led to the continued development of "high growth" sectors of the economy at the expense of the development of the rural sector.

Further it neglects to consider the mechanisms through which road user savings are translated into new output (principally agriculture). No consideration is given to possible constraints which will limit the development impact of the road. The use of this measure captures the transport cost savings which is a means of development but not development per se.

In light of the discussion in Section 2.1 above, a further deficiency in this approach is its lack of consideration for those economic and social objectives which are entirely relevant to rural development and project appraisal within this sector.

2.2.1.2 Benefits = Consumer and Producer Surplus

In the analysis of rural roads where the user cost savings method is not feasible because of very little existing traffic or no existing traffic, Carnemark et al (1976) recommend that the benefits be measured by the producer and consumer surplus approach. The approach involves the forecasts of variables such as costs, prices, quantities, etc. for each particular crop both with and without the project over its lifetime and the use of these variables to estimate approximate demand and supply functons. It is recognized that this is a difficult task and though the method is elegant, the practicality of this approach when applied to the analysis of feeder roads is questionable.

The accounting procedures again can incorporate the use of efficiency prices to adjust for market distortions and utilize the methods of NPV, B/C or IRR to compare benefits and costs and thus justify investment decisions.

It is also obvious that this approach is incapable of taking into consideration those economic and social objectives which are relevant to the rural development effort.

2.2.1.3 Benefits = Δ National Income

The Gross National Product of a nation can be defined as the sum of the market value of goods and services consisting of Personal Consumption Expenditures, Gross Private Capital Formation and Government expenditures and investments. The measure of benefit - national income - is the corresponding value which is paid to the primary factors of production (land, labor and capital).

Mohring (1976) noted that several studies [(Bos and Koyck (1961), Brown and Harral (1965), Friedlaender (1965), Tinbergen (1957)] have proposed that the contribution to national income be used in the evaluation of transportation investments instead of the traditional consumer and producer surplus measure of benefit. It is interesting to note that in studies where numerical calculations were performed the former measure resulted in substantially larger changes than the latter, - the difference being attributed to the failure to account for indirect benefits by the consumer and producer surplus measure.

Odier (1976) in his treatment of this topic identifies the following effects which contribute to the increase in national income measure:

(1) the direct primary effect which is the increase in national income in the planning sector/sectors.

(2) the indirect primary effects which concerns the sectors "upstream" from the above sector/sectors.

(3) the induced effects which come from the sectors located "downstream" from 1).

(4) the secondary effects which consist of the multiplier effects of 1).

This method is quite complex and requires collection of an enormous amount of information. However, for the feeder road problem, the use of induced agricultural production which will constitute the majority of the direct primary effect, will probably suffice as an approximation for the change in national income measure.

Similarly in this case, the accounting procedures can incorporate the use of efficiency prices to adjust for market distortion and utilize the methods of NPV, B/C or IRR to compare benefits and costs and thus justify investment decisions.

The single-objective methods described above have several comparable methods, but most fall short in quality or in application to the rural situation. Some of these alternative methods are: (1) the minimum-cost method, in which project selection is made on the basis of minimum cost, thus failing to estimate benefits and precluding from consideration more economically efficient projects. The minimum cost method consider no income, employment or production effects. (2) The alternative-cost method is used in situations where benefits are difficult to estimate and as a proxy for benefits we use costs of alternative projects. The method is similar to cost-savings in that it does not consider benefits, thus possibly omitting the optimal solution from consideration.

2.2.2 Multiobjective Analysis

The review of the single objective analysis methods has pointed out the main deficiency of those techniques. They are incapable of taking into consideration the various social and economic objectives relevant to the rural development effort. In order to overcome this omission, the emerging method of project evaluation, multiobjective analysis, incorporates both economic and non-economic objectives into the evaluation framework.

Much has been written concerning multiobjective analysis over the past few years and researchers from such diverse fields as management, engineering, psychology (cognitive), etc. have devoted much interests in this area. Friesz and Evans (1977) have presented four paradigms under which most of the prevailing methodologies on multiobjective analysis can be classified. These are:

Paradigm 1

Each attribute may be valued in terms of some common reference attribute or "numeraire." Thereby, the many dimensions or attributes characterizing a given system design (project) may be collapsed into one dimension. The value of a given system is proportional to the total amount of the numeraire which it manifests. The design (project) providing the greatest amount of the numeraire is "optimal."

Paradigm 2

Each attribute is not expressible in terms of a single numeraire but adequate consensus exists on the part of system users that a utility function may be defined which expresses the level of satisfaction of the users with each alternative design (project). The system design (project) with the highest utility level is "optimal."

Paradigm 3

Neither the single numeraire nor adequate consensus exists to define a single utility function. This may occur for two reasons.

a) there are several statistically distinct groups of users in the user population, each characterized by a distinct utility function (two utility functions are distinct if they result in different ordinal rankings of alternative system designs (projects); and/or

b) an individual user group may have multiple objectives or measures of utility against which a system design (project) must be compared; the individual or user group is uncertain of the relative importance of the objectives. Consequently the separate objectives cannot be translated into a single utility function.

The multiplicity of utility or objective functions means that it is not generally possible to analytically determine a single optimal system design (project) without additional preference information. One may proceed however by narrowing the original list of alternatives to a set of "efficient" (or non-inferior) system designs, however the final design (project) choice must be made on political grounds, exogenous to any analytical framework.

Paradigm 4

In the event multiple objectives or utility functions exist it is possible to bring the involved party or parties to a best compromise solution through an iterative analytical process. In these analytical processes the most efficient consequence of selected assumptions concerning the relative importance of each objective are presented. The involved parties (party) then provide(s) inputs to the analytical process which result in a new set of assumptions concerning the relative importance of objectives. The efficient consequences of these assumptions are displayed. Further iterations take place until the involved parties (party) reach(es) a final decision.

The techniques corresponding to the description of paradigm 1 are those that are traditonal to benefit-cost analysis methodology. The common feature of the techniques belonging to this group is the existence of a numeraire which is a common unit of account for all the inputs and outputs of projects. As an illustration: the numeraire used by the UNIDO guidelines (1972) authors is consumption, which is measured in domestic prices; Little and Mirrlees (1974) used a public income numeraire measured in world prices. This class of techniques can also be referred to as the "aggregate" method of multiobjective analysis.

By using the idea of "social pricing" more than a single objective can be implicitly considered. Social prices are opportunity prices of resources that consider the impacts on distribution of income between consumption and investment (growth objective) (UNIDO guidelines, pages 173 - 178) or the social prices that are derived by Squire and van der Tak (1975) incorporates considerations of distribution between the rich and the poor (equity objective), in addition to the consideration of distribution between consumption and investment. A special form of the utility function* is used by Squire and van der Tak (1975) such that the egalitarian bias of distribution weights can be summarized in just one

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*Specifically the utility function used was:

$$u(c) = \frac{1}{1-n} c^{1-n} \quad \text{for } n \lesseqgtr 1$$

$$u(c) = \log_e c \quad \text{for } n = 1$$

where c is consumption and n is a parameter.

parameter, n. Bruce (1976) applied this methodology and obtained national parameters for Thailand, Malaysia and the Philippines. The rationale of the "guestimates" of n are quoted below.

> "The elasticity of marginal utility (n) equal to 1.0 probably reflects fairly accurately the dual commitments to growth and equity of the Philippine Government."

> "Turning now to the subjective parameters, the Malaysian Government has a high commitment to equity and increasing employment. In part, this stems from the unequal distribution of income and wealth as between the Malay, the Chinese and the Indian elements of the population and a major goal in the current development plan is to reduce the racial inequalities. A value of about 1.5 for the elasticity of marginal utility (n) would seem therefore, to reflect the objective functions of the Malaysian Government."

For Thailand,

> "Turning now to the subjective parameters, a preliminary value of 1.00 was given to the elasticity of marginal utility (n) on the grounds that the Thai Government has a modest commitment to a more egalitarian distribution of income."

An examination of the rationale behind these "guestimates" will reveal a rough and insufficient basis, more so, when the values of the distribution weight, d (corresponding to a particular income group) implied for each particular value of n is highly sensitive to the values of n, especially at the lower levels of existing consumption level. (See Table 2-1).

Non-economic objectives are also considered in the "numeraire class" of evaluation techniques by the use of appropriate "metric conversions" which are typically difficult to determine and impossible to agree upon

TABLE 2-1

VALUES OF THE CONSUMPTION DISTRIBUTION WEIGHT (d) FOR MARGINAL CHANGES IN CONSUMPTION

VALUES OF DISTRIBUTION WEIGHT (d)						
AT EXISTING CONSUMPTION LEVEL (c)	AT RELATIVE CONSUMPTION LEVEL ($\bar{c}/c$)	AND WHEN n EQUALS				
		0	0.5	1.0	1.5	2
10	10.00	1.00	3.16	10.00	31.62	100.00
25	4.00	1.00	2.00	4.00	8.00	16.00
50	2.00	1.00	1.41	2.00	2.83	4.00
75	1.33	1.00	1.15	1.33	1.53	1.77
100*	1.00	1.00	1.00	1.00	1.00	1.00
150	0.66	1.00	0.81	0.66	0.54	0.44
300	0.33	1.00	0.57	0.33	0.19	0.11
600	0.17	1.00	0.41	0.17	0.07	0.03
1000	0.10	1.00	0.32	0.10	0.03	0.01

*Average consumption ($\bar{c}$)

Source: Table 1, pg. 64, Squire and van der Tak, 1975.

between planners and decision makers. For instance, if health was a desired social objective for a particular region, then in analyzing a feeder road program we would need an estimate of a health measure say average number of sick days/worker, upon which we could apply the average value of productivity/worker/day to get the dollar value of a sick day and hence the dollar value, with respect to the health objective, contributed to our aggregate measure. Similar examples of metric conversions can conceivably be developed for any objective desired and the recursive application of these conversions to each objective becomes the main element of aggregate multi-objective analysis. This type of evaluation process becomes highly subjective, inconsistent and distorted with respect to the true value contributed by each objective factor.

The techniques characterized by paradigm 3 assumes that there is a number of distinct interest groups and there is no possibility of achieving a consensus from them. The analyst's role in this context narrows down to the search for the "pareto-optimal"* or "non-inferior" set of alternatives and the final choice is political and exogeneous to the structure. The set of pareto-optimal alternatives that is located is relevant only in the context where a single alternative needs to be selected, for instance the case where the alternatives are all variants of the same project. In the context of the rural feeder roads problem

*By the "pareto-optimal" set, we mean to refer to that set of alternatives that is not dominated.

where many small unique projects have to be selected from an even larger set of potential projects*, the location of the set of pareto optimal alternatives is not very relevant as an aid in decision-making.

The techniques characterized by paradigms 3 and 4 are very realistic representations of scenarios in developed countries where there are numerous involved parties with its respective interests and capabilities to participate and advocate in the decision process. In the context of the rural development effort and for this particular study we are assuming that there is a universal commitment to the achievement of the accepted articulated goals and the need to model different preferences among different interest groups is not relevant. Thus we are assuming that a single set of social preferences will be articulated. Thus in anticipation of the decision scenario we will be handling the characteristics of paradigm 2 obviously fit our problem.

For the techniques of paradigm 2 the element of subjectivity remains but at least the value judgments are articulated explicitly by the appropriate elected or appointed official contrary to the implicit value judgments implied by the "metric conversions" by inappropriate articulators at irregular steps in the planning process. Keeney and Raiffa (1976) have developed specialized techniques for determining the appropriate mathematical form of the utility function depending on

*See the case of Kenya described in Section 3.1

the type of independent relationships among and between the attributes. There are theorems which state the appropriate functional form for different types of independent relationships. There are three basic forms of these utility functions:

(1) Additive form

(2) Multiplicative form

(3) Mixed additive/multiplicative form

For cases where more than three attributes are involved the analytical effort needed to determine the multiplicative or the mixed additive/multiplicative form is quite enormous and the analysis tends to become very complex.

The cognitive school of psychoanalysis has found through various experiments that people use the linear additive form of the utility function in decision making. Thus the specification of alternative forms does not add much explanatory power but adds much unnecessary complexity in the determination process. Cogntive psychoanalysts like Slovic, Lichtenstein and Anderson* are convinced that humans integrate information linearly.

In summary then, we have reviewed the existing multi-objective evaluation techniques and we find that structuring the multi-criteria framework for the rural roads appraisal problem according to the characteristics of paradigm 2 will best meet the requirements of

*See Chapter 1 in Rappoport and Summers (1973).

the need to account for the multiple objectives of the rural development effort in the appraisal of rural road projects. The economic objective however will still remain as an important criteria and the prediction of economic benefits is a very important step in the analysis. Thus we now change our emphasis and review the literature with regards to the various models which have been proposed as forecasting techniques for the economic benefits of rural road projects.

2.3 FORECASTING TECHNIQUES

In the project appraisal of feeder roads it is recognized that the forecast of economic benefits is a very important step in the process. The inter-relationships of the road with the project area can be very varied and complex depending on the social, economic and institutional constraints. Some theoretical attempts have been made to develop some techniques that will be useful in forecasts of the effects of the roads. In the following sections a discussion will be made of the attempts in this area. A general observation that can be made is that the use of any particular method is heavily contingent on the availability of the necessary data.

2.3.1 A Linear Programming Approach

Arturo Israel (1970) in his paper "Appraisal Methodology for Feeder Road Projects" surveyed and evaluated the then feeder road appraisal methodologies in developing countries. Consistent with his definition of feeder roads, he concluded that the user cost savings approach to the estimation and quantification of benefits was inadequate because none or very little traffic exists and that there was relatively a small amount of induced traffic.

The contention was then that "development" benefits would be more important and would outweight "user cost savings" benefits. Israel proposed that the quantification of these "developments" benefits was necessary and possible for feeder road projects which were usually considered only as part of agricultural package programs.

The forecasting approach that Israel proposed was a linear programming one. Agricultural value added was used as the objective function. The productive potential of the area, the institutional characteristics and transport costs were some of the constraints that were used. This was important because the existing appraisal techniques often neglect analyses of the inter-relationships between transportation and the productive structure of the rural economy. The approach was also confined to the level of the small regional economy.

The first empirical application of the model proposed by Israel is being carried out in the Taiz-Turba feeder road influenced region in the Yemen Arab Republic. According to the "World Bank Research Program, Abstracts of current studies, October 1976" the base socio-economic survey has been completed and a "during construction" follow-up survey was also conducted in August/September 1976. A full scale "after road completion" survey is expected to be carried out in 1978. It will be interesting to see the results of this attempt.

A critique of this approach will become clear if we explore the assumptions made. All the social relationships of the region were defined in the constraint system. The maximization of the agricultural value added within the constraints assumed that all parties would act as a group in this manner. Thus a weak point would be that each farmer is assumed to have a similar proportion of each resource and was maximizing over the same set of input constraints. This is clearly not necessarily so. Further, it is hard for the constraint system to capture perfectly all the peculiar characteristics present in different situations.

2.3.2 Aggregate Regression Analysis Approach

In attempting to relate the impact of certain economic and social factors on agricultural output Dayal (1966) proposed a function having the general form of:

$$Y = f(I,L,F,A,E,R,N.H,u)$$

where

Y = Agricultural output

I = Investment in agriculture

L = Agricultural work force

F = Fertilizer consumption

A = Area of agricultural land

E = Agricultural education

R = Research and extension in agriculture

N = Nutrition

H = Health

u = residual error element

He utilized available cross-country and time series data and dropping terms for which no data was available. Utilizing Cobb-Douglas production functions, he found most of the coefficients were insignificant. With linear production functions he had better results with 3 coefficients at 1%, 2 coefficients at 5% and 1 coefficient at 10% significance.

The following model was specified:

$$Y = a_0 + \sum_i a_i X_i \qquad i = 1, 2 \ldots\ldots 9$$

where

Y = the average annual increase in agricultural output in wheat equivalent tons

X_1 = the annual average gross fixed capital formation in U.S.$

X_2 = the annual average increase in agricultural employment

X_3 = the annual average increase in fertilizer consumption

X_4 = the ratio of livestock products increase to total agricultural output increase

$X_{4a} = X_3 * X_4$

X_5 = the average agricultural land (including grasslands and meadows) increase

X_6 = the average annual number of agricultural graduates from third level institutions

X_7 = the average per capita daily calories consumption increase

X_8 = the average annual per capita daily protein consumption increase

X_9 = the average annual per capita daily animal protein consumption increase

X_1 to X_5 are considered his economic explanatory variables while X_6 to X_9 are the social variables. Traffic could be obtained by knowing the exportable surplus which is obtained by subtracting subsistence consumption, loss from Y.

Dayal obtained high R^2's (near 1.0). He was able to model the variance between countries quite well but within each country he lost all the information about the variance which is the aspect of interest in our current discussion.

2.3.3 A Disaggregate Behavioral Modelling Approach*

The inadequacies of the model proposed by Dayal for our purposes spur the development of this approach at the disaggregate level of the farmer.

The general form of the proposed fuction is:

$P[c_f] = f[x_i, u] \quad i = 1,2,\ldots\ldots,8$

where

$P[c_f]$: the probability that farmer f will convert available land c to production of cash crops;

x_1: a measure of the basic subsistence population living on the output of the farm;

x_2: a measure of the land and capital owned by the farmer f. For very large farms this can be a dummy variable;

x_3: a measure of the standard of health found on the farm. A dummy variable could also be used for presence of mid-wife level medical attention;

x_4: a measure of the nutritional intake of household f;

*Some of the ideas for this were initially proposed by Fredric Berger in some unpublished notes.

x_5: a measure of the generalized price of one ton-mile between the center of the farm and the market;

x_6: a measure of the technology of present farming practices;

x_7: a measure of the value of the subsistence wage;

x_8: a measure of the demand conditions;

u: a measure of random error.

This model can relate the explanatory variables to the section of cultivatable but uncultivated land. The probability of the farmer converting his land to cash crop cultivation can be predicted. When this is aggregated for the region we have the probability that the available land in the region will be devoted to cash crop cultivation. Together with other data concerning the crop yields, available land, etc., we can predict the expected cash crop yield.

As yet this model has not been tested with empirical data. The problem is, of course, that much of the required data is not available. Subject to the availability of data, the form of the function might have to be changed, but this seems to be an approach in the right direction.

2.3.4 Specific Project Analysis

This is not a forecasting technique in the sense of those previously discussed. Rather it, according to Odier (1976), "consists of an analytical study of the consequences of the project, comparable to the methodology used for studying the profitability of agricultural development projects, irrigation projects and industrial projects."

Some steps in such analysis (Odier, 1976) might consist of:

(1) determination of the road zone of influence.

(2) determination of the inventory of production potential in both physical and human resources. Probable outputs may be obtained from a technical study with consideration of the agronomic, climatic, and hydraulic conditions with consideration of social and cultural characteristics of the people.

(3) a study of the demand conditions for the desired agricultural output.

Basically this method implies a detached scrutiny of every project without the help of mathematical models. If we are to assume that the mathematical models discussed previously are transferable then this would seem to be an unnecessary task. However, the question of which approach to use will depend on the availability of the required data of the different approaches and the degree of transferability of different models. The preferences and biases of different analysts are, of course, a decision factor too.

CHAPTER 3: A MULTI-CRITERIA APPRAISAL FRAMEWORK

3.1 THE STRUCTURE OF THE FRAMEWORK

The feeder road appraisal problem can be visualized as a choice of many small projects, where each project has several important selection criteria, where each measure is denominated in its own units and where the choice of these small projects has to be made from a much larger set of small projects. As an illustration, the case of Kenya* fits this description. In the Fall of 1974 plans were made for a program to improve about 12000 km of secondary and minor roads but there were 30000 km of potential candidates. In addition, a major program to improve 16000 km of "low-class rural roads" to all-weather conditions was looked into. These had to be selected from a theoretically possible total of 100,000 unclassified roads. The Kenyan Ministry of Works articulated the desire for the selection criteria to include contributions to socio-economic impacts of the roads. This clearly indicates the need for a multi-criteria appraisal framework to impart a more valid basis for the investment decisions.

The general structure of the multi-criteria problem can be stated as a process consisting of the identification of: (1) the relevant and important criteria of interest; (2) the ways in which the measures of

*See "The Impact of Low-Class Roads Upon Rural Development", IBRD meeting discussion notes, 1976.

these criteria can be collected (or measured); and (3) the ways in which the measures of the criteria can be combined to form an explicit value structure such that it can be used for evaluation or as the basis for decision-making. Thus the gist of the problem is the way in which the multi-criteria problem is structured following the process just described.

We have reviewed the single objective and multi-objective analysis literature, specifically those evaluation techniques applicable in developing countries, in Chapter 2. We found that the characteristics of some of the multi-objective techniques corresponding to paradigm 2* best fit the requirements to account for socio-economic objectives in the appraisal of rural road projects. Thus in the present chapter, an implementable framework for the multi-criteria appraisal of rural road projects is structured.

Five criteria have been selected to be incorporated in the framework; these include:

(1) economic benefits criteria

(2) economic costs criteria

(3) distribution criteria

(4) accessibility to social services criteria

(5) employment criteria

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*See the four paragigms under which most of the multi-objective analysis techniques can be classified in Section 2.2.2.

These represent just one possible set of criteria and cannot be claimed to be a universal representation in the accounting of socio-economic objectives of the rural development effort. The findings of further research may suggest some other relevant criteria; however, the multi-criteria framework that is structured is independent of possible changes in the relevant criteria or the addition of more relevant criteria.

In Section 3.2 the relevance and measures with which each of the above five criteria might be captured are presented. Section 3.3 is a brief treatment of the temporal question as the measures of the criteria from a particular project will occur not only at a point in time but also over time. The various ways in which the utility or psychological value for each criteria can be assessed is discussed in Section 3.4 Finally Section 3.5 explores the significance and implications of various hypotheses regarding the way in which the measures of the five criteria can be combined to form an explicit value structure from which the decision-making can be performed.

3.2 CRITERIA FOR EVALUATION

3.2.1 Economic Benefits Criteria

The sole use of economic criteria has been the traditional practice in the appraisal of transport projects. The measures of economic criteria are therefore well documented* and widely known. The economic measures of

*See Mohring (1976), "Transportation Economics" and Carnemark et al (1976), "The Economic Analysis of Rural Road Projects."

benefits that were discussed and explored in the literature review in Chapter 2 include user cost savings, producer and consumer surplus and national income.

The sole use of user cost savings as a benefit measure was cautioned against because its application assumes that the bulk of the benefits will stem from the savings on normal traffic, while development benefits are less important. In the context of appraising feeder road projects the development benefits are more important because the level of normal traffic is very low or none in some instances (the case of opening of new lands). But exceptional cases do surface where this sole measure will suffice; for example, cases where the lack of adequate transportation services is the only stumbling block for increased economic activity.*

However, in general the user cost savings measure is an inadequate measure for feeder road projects and an alternative measure is needed. The producer and consumer surplus measure, although conceptually attractive, is not recommended in the context of feeder road appraisals because the approach necessitates the forecasts of "approximate" demand and supply functions which is recognized as a very difficult task and correspondingly not a very feasible option in this instance. A good candidate for this is the national income measure. This measure is the corresponding value which is paid to the primary factors of production (land, labor, and capital). A good approximation for this measure is the use of induced

*See Roberts (1974), "An Approach to the Analysis of Feeder Roads in Developing Regions."

agricultural production since most of the induced economic productivity (at least initially) in most rural areas will be in the agricultural sector. Thus the measure of the economic benefits is the difference in the present value of the predicted expected value of the agricultural activity with the implementation of the project with that of the no-project alternative.

Table 3-1 shows how the various parameters can be tabulated and used by the appraisal team to determine the expected value of the agricultural activity by the type of crop for each identifiable homogeneous group of farmers that might have the same characteristics resulting in the exhibition of similar behavior. It must be noted that this just serves to illustrate basically how the prediction of induced agricultural activity can be analyzed, and that there might be other explanatory parameters which the different appraisal teams (who will know "best" the probable outcome) might suggest and which they feel may have a probable influence on the outcome. It is also true that further research might be needed to determine or contribute towards better understanding of all the possible important determinants that affect the economic behavior of the peasants.

3.2.2 Economic Costs Criteria

The measure of economic costs is a relatively more straightforward element and correspondingly does not need a very detailed exposition.

TABLE 3-1

ASSESSMENT OF AGRICULTURAL PRODUCTION

TYPE OF CROP: YEAR:

Type of Group	Cultivatible Areas A	"Old" Average Yield Y_o	"New" Average Yield Y_1	Predicted Average Unit Market Price P_1	FROR* to Farmer	Demand Conditions	Other Relevant Parameters	Subjective Assessment of Pr [cultivation] Pr	Expected Value $[Pr x P_1 x Y_1 x A + (1-Pr x P_1 x Y_o x A]$

*Financial rate of return

Some general guidelines are:

(a) the inclusion of all relevant expenditure items related to the construction and maintenance of the road; and

(b) the inclusion of other components (complementary investments) that are deemed necessary and which are incorporated as part of a package in formulating the project.

3.2.3 Distribution Criteria

The need for the distribution of project economic benefits to be considered in an explicit manner is very widely recognized. The concern here is with the distribution of benefits among the population in the area of influence of the project. It has been contended earlier that the alleviation of poverty among the poorest of the rural population is a primary goal, but that these people seldom reap much of the benefits of public investment projects (in this instance rural development projects). Therefore, the accounting of just who the project beneficiaries are is needed.

Thus, this class of rural poor has to be identified. It will be noted here that in different countries the definition of this class might differ. The choice of the relevant operational parameters will be guided by the feasibility of obtaining the data. The more obvious choice that surfaces is the consideration by income groups. It has been contended earlier that the prediction of the distribution of the economic benefits is hard in practice. A way around this problem is the use of a proxy measure. A likely and promising candidate for this is the accounting of the land ownership by the relevant income group or groups of interest.

It must be stated that although this is not a perfect measure, its attractiveness is two-fold. First is the relative ease with which it can be measured and second is the good representation it makes in tracing the distribution of the major economic benefits of the project. Some assumptions have to be made to make this a valid measure. These are:

(1) The cultivatable land owned by the target group is in general less than ten hectares per family.

(2) Economic conditions of perfect competition exist.

(3) Average productivity of land is uniform.

(4) The share of economic benefits is proportional to land ownership.

To illustrate the usefulness of this measure, consider the following two extreme cases:

Case 1: The project area of influence consists of a small community of 500 persons, all of whom are presently sustaining on income levels below that of the target income group. The remaining cultivatable land, with the help of some extension workers and new inputs (seeds, fertilizers, etc.), will be opened up and planted with mostly cash crops plus sufficient consumption crops for the populace. The ownership of the land, amounting to 1000 hectares, is homogeneous resulting in a homogeneous share of the new output of agriculture.

Case 2: The project area of influence consists of a community of 300 persons. About 250 peasants are either farming a subsistence level of existence or are working for the five relatively rich families of the community. The introduction of the road will give rise to big increases in agricultural production because the five rich families control and own almost all of the available cultivatable land. Though the predicted induced agricultural production is expected to be large, the share of this by the "subsistence group" is expected to be negligible.

3.2.4 Accessibility to Social Services Criteria

It has been stated that the consideration of how the introduction of the transport improvement has affected the accessibility to social services is important. This, however, has to be considered first in the context of the direct effects of the transport improvement itself and secondly in the context of existing and proposed facilities. To elaborate, the transport improvement will in some instances reduce traveling time or in other instances enable the affected population to reach existing social services facilities in nearby towns. From another angle, the inclusion of proposals, such as in complementary investments or as a part of an integrated rural development project, to build new social services facilities nearby or in the project area itself is an important element in measuring the degree of accessibility.

The effect of the provision of the road on the accessibility to social services is being looked at from the point of view that the road allows the direct access of the area to these services specifically either from traveling facilities which bring the services (health) or from the fact that it makes it possible to build some of these facilities within reach of the peasants considering the present means of transportation as it is now possible to bring in the necessary and required personnel for these purposes.

The accessibility to facilities in nearby towns, not reachable by the present transportation means of the majority of the peasants, for example by walking, animals, bicycles, etc., will not be considered because we are dealing with areas provided with new access or improved access and the question of whether the peasants will have motorized vehicles to reach these facilities at least initially will not be easily predictable or justifiably handled.

To summarize, the present appraisal framework considers the provision of facilities contributing to this criteria as exogenously given (though the issues of the necessity of their provision has been discussed previously), and selects the projects by considering how the criteria measures might be maximized by the provision of the transport facility. The way in which the project (or set of sub-projects) are formulated is part of the design problem and will be briefly treated in Section 4.1.

Specifically, then, the contribution to this criteria will be contained in two measures: the accessibility to health services measure and the accessibility to educational facilities measure. The sum of these two measures assuming equal importance will be the accessibility to social services measure. It will be noted however that other elements of social services could also be incorporated, but it will involve correspondingly more analytical work and collection of data which might be hard to obtain.

3.2.4.1 Accessibility to Health Services Measure

In structuring the accessibility to health services measure, the following five states of health standards might be considered:

H 1 : local midwives

H 2 : visiting trained nurses

H 3 : permanent trained nurses

H 4 : visiting health clinic

H 5 : permanent health clinic

If it is assumed that there will be no deterioration of services as a consequence of the project then Table 3-2 shows the possible changes that will result. The important point to note here is that the subjective assessment of the utility of change will depend on the degree of change and the result of the change, and that the appropriate articulator of these technical judgments will be the medical experts (for example, the state chief health officer). Table 3-2 tabulates a possible set of this utility of change using a 0 to 10 scale. The respective score can then be multiplied* by the number of people affected to obtain the total utility of change for the accessibility to health services measure.

*By doing so, it is assumed that the utility of change is constant for all the affected populace.

Table 3-2: ASSESSMENT OF THE UTILITY OF CHANGE IN HEALTH SERVICES

Type of Change	Subjective Assessment of Medical Experts
No change	0
H 1 to H 2	2
H 1 to H 3	5
H 1 to H 4	7
H 1 to H 5	10
H 2 to H 3	3
H 2 to H 4	5
H 2 to H 5	8
H 3 to H 4	2
H 3 to H 5	5
H 4 to H 5	3

3.2.4.2 Accessibility to Educational Facilities Measure

The approach to formulate the accessibility to educational facilities measure is similar to that used in formulating the accessibility to health services measure.

In terms of accessibility to educational facilities the contribution to this measure will only be considered if it is as a result of the provision of the transport facility. For example, the introduction of the road might allow the extension of the educational arm of the government administration to the area resulting in the introduction of general education programs,vocational education or adult learning programs. The discussion of what type of education (like formal primary and secondary education as opposed to vocational education or education to make the people better farmers) will not be entered into as this is in the realm of the education experts; nevertheless, intuitively the latter two types seem more relevant.

Consequently, the following four states of educational facilities will be considered:

E 1	: none	E 3	: vocational education
E 2	: general education	E 4	: adult eduacation

Table 3-3 shows the possible changes in states that are considered together with a possible subjective assessment of the utility of change by the appropriate education officials. The respective score can then be multiplied by the number of people served to obtain the accessibility to educational facilities measure.

TABLE 3-3: ASSESSMENT OF THE UTILITY OF CHANGE IN EDUCATIONAL FACILITIES

Type of Change*			Subjective Assessment of Educational Experts
No Change			0
E 1	to	E 2	3
E 1	to	E 3	6
E 1	to	E 3 + E 4	9
E 1	to	E 2 + E 4	7
E 2	to	E 3	4
E 2	to	E 3 + E 4	7

* The entire set of possible combination of changes has not been detailed. The listing represents the likely implemented changes.

3.2.4.3 Accessibility to Social Services Measure

Thus far the two measures, accessibility to health services and accessibility to educational facilities, have been specified. The resulting accessibility to social services measure will be sufficiently captured by the sum of the above two measures and we can define the units of this measure as ATSS units.

[Accessibility to social services measure] = [Accessibility to health services measure] + [Accessibility to educational facilities measure]

3.2.5 Employment Criteria

In attempting to include the considerations of employment in project appraisal some controversey has been stirred. Basically it involves the question of whether employment should be treated as an end or whether it should be treated as a means to meeting other ends or objectives.

Keesing (1972) argues that employment must be treated as a separate objective because the generation of employment will not emerge naturally from the process of pursuing traditional macroeconomic objectives.

But the arguments for employment to be treated as a means are also convincing (UNIDO 1972). One of the more important relations of employment is with that of the problems of income distribution, and the value of employment can be conveniently related to the redistribution objective. The desirable aspect of employment creation is that it creates a source of livelihood for the rural family and if directed at poorer classes of a country is an excellent channel for distributing more consumption to the poor, which is why it is argued employment should be treated as a means for the redistribution objective.

It is argued here that while it is true that the monetary remuneration to the employed poor is perhaps indicative of the distribution ends aspect of the creation of employment, the number of employed persons, especially in comparing cases whereby one is more labor-intensive and the other is more capital-intensive, is indicative of the need to treat this as a separate criteria. An additional important element of the employment measure is the ability to account for the degree of mobilization of labor (an important primary factor of production that desperately needs to be mobilized for productive purposes in many rural areas).

Operationally, this criteria can be measured by the number of man-days of employment that is generated or is a consequence of the implementation of the project. These employment man-days might include construction generated employment, agricultural production generated employment, etc.

3.3 TEMPORAL CONSIDERATIONS

The measures of the economic benefits and economic costs criteria occurs not only at a point in time but over time. An often convenient assumption used is to present these occurrences at discrete intervals, usually yearly ones. For project appraisal these yearly measures need to be aggregated to a single measure, usually the present value.

If B_t is the benefit measure at period t, there is associated with this benefit at period t a certain time weight W_t to reflect the different preferences associated with the measures occurring at different time periods. Thus the present value of the measure is given by:

$$PV\ (B_t) = \sum_{t=0}^{T} W_t B_t \qquad (3\text{-}1)$$

Where: T is the number of periods

To simplify the problem, it is usual to assume that the time weights, W_t will decline* at a constant rate:

$$\frac{W_t - W_{t+1}}{W_{t+1}} = \text{constant} = i \qquad (3\text{-}2)$$

Equation (3-1) can be written as:

$$PV\ (B_t) = B_o + W_1 B_1 + \frac{W_2}{W_1} W_1 B_2 + \frac{W_3}{W_2}\frac{W_2}{W_1} W_1\ B_3 + \cdots\cdots$$

$$+ \frac{W_T}{W_{T-1}}\frac{W_{T-1}}{W_{T-2}} \cdots\cdots \frac{W_2}{W_1} W_1\ B_T \qquad (3\text{-}3)$$

Notice, however, that equation (3-2) can also be written as:

$$\frac{W_{t+1}}{W_t} = \frac{1}{1+i} \qquad (3\text{-}4)$$

*According to the UNIDO (1972) authors, "the assumption that i is constant over time is one that can be defended only on the grounds that such an approximation to a more complicated path of i is a reasonable one in view of our ignorance about the future." (page 156)

If equation (3-4) is substituted into equation (3-3) the result is:

$$PV\ (B_t) = B_0 + \frac{B_1}{1+i} + \frac{B_2}{(1+i)^2} + \quad \frac{+B_T}{(1+i)^T} = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t} \qquad (3\text{-}5)$$

The value of i is often referred to as the social rate of discount and the assessment of the "correct" value of i has been subjected to unending debate and research.

Blitzer (1973) has a pessimistic conclusion regarding the social rate of discount. There is no clear way for its determination, and it is hard to substitute a surrogate for it. His final contention is that perhaps discounting should be performed using a few alternative discount rates, and the choice of a particular rate should be a political responsibility rather than an economic one.

In this present study, the debate on the "correct" social discount rate will not be entered into and an "arbitrary" discount rate will be chosen. This choice will appear to be a valid approximation if the same i is used in the appraisal of all the projects.

As a final note, the contributions to the employment measure also happen at different time periods but no discounting of this measure will be performed; that is, the employment measure is assumed to have the same value over time.

3.4 UTILITY ASSESSMENT TECHNIQUES

The contributions to the measures of the five criteria are in different physical measures: the economic benefits and economic costs criteria are denominated in monetary units, the distribution criteria is denominated in hectares, the accessibility to social services criteria is denominated in ATSS units and the employment criteria is denominated in man-days. Thus the measures are non-commensurate and the physical measures need to be transformed to utility (or psychological value) measures.

Various utility assessment techniques might be applicable. First, in the category technique, a number of discrete categories is fixed and the decision-maker has to classify the measure of a single criteria for each project to one of these categories. When the measure of that criteria for all the projects has been categorized the numerical worths can be determined. However, the numerical values determined from this technique will be very approximate.

The gamble technique consists of lotteries which can be constructed by varying the level of the measure or the probabilities of occurrence until the decision-maker is indifferent between the lottery and a certainty equivalent. As an illustration consider the following:

$$L_1 = [(x_1, 0.5)\ (x_2,\ 0.5)] \ > x_3 \qquad (3\text{-}6)$$

Where: L_1 is a lottery which has a 0.5 probability of achieving x_1 and a 0.5 probability of achieving x_2.

$>$ means is preferred to.

x_3 is a certainty level of the measure.

If the certainty level is varied we will reach a point such that:

$$L_1 = [(x_1, 0.5)\ (x_2, 0.5)] \sim x_4 \qquad (3\text{-}7)$$

which means the lottery L_1 is indifferent to the level of the measure of x_4.

The gamble technique can be a useful device for obtaining the utility function of the individual criteria if the decision-maker can be "educated" to be familiar with the procedure. It also requires the analyst to spend quite a bit of time with the decision-maker.

Finally, the direct technique which is the most straightforward requires the decision-maker to directly assign numerical values to the various levels of attainment of the measure. There are two ways in which the numerical values can be structured. One way is to anchor one extreme point of the measure, and to compare all the other values of the measure with this anchor in assigning the numerical values reflecting the utility. The second way, which is the one more suitable for application to the present framework, involves anchoring the two extreme values of the measure along a scale of 0 to 100. Then the values of the measure corresponding to a few convenient points, specifically the mid-point, quarter-point and the third-quarter-point, can be assessed and linear interpolation can be performed to obtain an approximate but sufficiently adequate preference function. However, additional points could easily be assessed in a similar fashion if a finer representation is required.

In summary, the discussion has reviewed three alternative techniques for assessing the individual criteria utility function and found the direct technique to be the more attractive technique. However, in practice, it depends very much on what the decision-maker prefers and is comfortable with in choosing an assessment technique. Also, the three techniques reviewed do not constitute all the available techniques that have been developed in this fast growing field of research, and the special characteristics and environment of different cases may dictate the necessity of structuring other assessment techniques.

3.5 THE RANKING OF THE PROJECTS

Thus far, the relevant criteria of interest have been identified, the measures with which the criteria can be measured have been delineated and the techniques for determining the individual criterion preference (utility) function has been presented. As a final step in the formulation of the framework, the way in which the various measures can be combined to form an explicit value structure as the basis for the appraisal or ranking of the projects will be delineated.

For the combination of the different criteria, information on the preference (weight) on each criteria will need to be elicited from the appropriate decision-maker (policy-maker). Thus the identification of the decision-maker is also an important step. However, it is usually quite obvious who the decision-maker will be for a feeder roads program. It can be the director of the agency that is planning the program or in some instances even the Minister of Transportation or Public Works. In the event that there is more than one decision-maker, a compromise will need to be elicited from them concerning the relevant weights.

The significance and implications of three alternative hypotheses concerning the articulation of the weights are presented below. These are:

(1) the articulation of equal weights

(2) the articulation of cardinal weights

(3) the articulation of ordinal weights

3.5.1 The Articulation of Equal Weights

This hypothesis (which is really a special subset of the second hypothesis) involves the assumption that the criteria are articulated to be equal in importance. This means that the weights on all the criteria are equal. Thus, the projects can be ranked by the value of $WVUC_1$ where:

$$WVUC_1 = u(x_1) + u(x_2) + u(x_3) + u(x_4) + u(x_5) \tag{3-8}$$

$WVUC_1$ is a linear additive function of the utility of the criteria with a weight of unity on each criteria.

$u(x_i)$ is the utility function of criteria measure i.

If this articulation represents the "true" social articulation by the appropriate decision-maker then the analyst can proceed directly with the analysis using the above formulation without the need of further information from the decision-maker.

3.5.2 The Articulation of Cardinal Weights

This hypothesis assumes that the decision-maker would be capable and willing to articulate explicit cardinal weights for each of the criteria. This means that the projects can be ranked by the value of $WVUC_2$ where:

$$WVUC_2 = \sum_i w_i \; u(x_i) \tag{3-9}$$

$WVUC_2$ is a linear additive function of the utility of the criteria with an explicit weight on each criteria.

w_i is the explicit weight on criteria i.

$u(x_i)$ is the utility function of criteria measure i.

Thus, the analyst will need to elicit from the appropriate decision-maker/body the "correct" articulation of the weights, w_i's. It is recognized that the articulation of cardinal weights is a difficult task and often the decision-maker might have difficulty in correctly articulating the appropriate "social weights" due to conceptual problems or even to political sensitivity problems. For instance, the subject of particular weights on certain criteria might result in certain politicians using it for political purposes. This method also requires that the analyst will be able to spend quite a bit of time with the decision-maker.

3.5.3 The Articulation of Ordinal Weights

When the decision-maker is not willing and/or incapable of articulating cardinal weights, this hypothesis assumes that he will be willing and able to articulate ordinal ranking to reflect the relative importance of the criteria.

The ordinal ranking of the criteria is a relatively small amount of information when compared to the cardinal weights for each of the criteria. However, by utilizing some concepts of linear programming problems, the analysis can be taken further. The formulation presented is that initially developed by Cannon and Kmietowicz (1974) for application to decision making problems under uncertainty.

Now, for each project let's deal with the problem of determining the maximum and minimum weighted values of the criteria; that is, $WVUC_3^{MAX}$ and $WVUC_3^{MIN}$ respectively. One way of formalizing this problem is to treat it as two linear programming problems. The formulation is:

$$\text{Maximize (Minimize) } WVUC_3 = \sum_{i=1}^{m} W_i \, u(x_i) \qquad (3\text{-}10)$$

Subject to:

$$\sum_{i=1}^{m} W_i = 1 \qquad (3\text{-}11)$$

$$W_i - W_{i+1} \geq 0 \quad (i = 1, \ldots\ldots, m-1) \qquad \text{(this reflects the ordering of the criteria)} \qquad (3\text{-}12)$$

$$W_i \geq 0 \quad (i = 1, \ldots, m) \qquad (3\text{-}13)$$

By the application of two transformations:

$$Z_i = W_i - W_{i+1} \qquad (3\text{-}14)$$

$$(i = 1,2,\ldots.m-1)$$

and

$$M_i = \sum_{j=1}^{i} u(x_j) \qquad (3\text{-}15)$$

$$(i = 1,2,\ldots.m)$$

the above formulation can be reduced to the following formulation*:

$$\text{Maximize (Minimize) } WVUC_3 = \sum_{i=1}^{m} M_i Z_i \qquad (3\text{-}16)$$

subject to:

$$\sum_{i=1}^{m} iZ_i = 1 \qquad (3\text{-}17)$$

$$Z_i \geqq 0 \qquad (3\text{-}18)$$

$$(i = 1, 2,\ldots.m-1)$$

The problem has now been transformed to a form whereby there is only one functional constraint. The optimal solution to a linear programming problem of this form will have only one of the functional variables Z_i positive with all other functional variables equal to zero.

Following this it can be observed that Equation (3-17) becomes

$$Z_i = \frac{1}{i} \qquad (3\text{-}19)$$

since only one variable Z_i will be non-zero.

The important result that follows is that $WVUC_3$ will be maximized (minimized) according to whether M_i/i is maximized (minimized). The process is thus reduced to the identification of the maximum (minimum) value from all the M_i/i or

*See Appendix B for full details of the derivation.

$$\sum_{j=1}^{i} \frac{u(x_j)}{i} \qquad (i = 1,2,\ldots m)$$

3.5.3.1 Maximax Decision Rule

From the analysis in the preceding section the results yield two parameters which can be used as the decision variable. The analysis yields the maximum weighted value of the criteria and the minimum weighted value of the criteria.

If the maximum weighted value of the criteria, $WVUC_3^{MAX}$ is used as the decision variable it is called the maximax decision rule. Thus, for each project:

$$WVUC_3^{MAX} = MAX\left[\sum_{j=1}^{i} \frac{u(x_j)}{i}\right] \qquad (3\text{-}20)$$
$$i = 1,2,\ldots m$$

and the projects are ranked according to the values of $WVUC_3^{MAX}$ for the maximax decision rule.

The ranking of the projects that will be produced by this decision rule can be said to be of a "less conservative" or "more aggressive" nature. If a situation arises whereby a contribution to the most preferred criterion is exceptionally good relative to any of the following criteria which might be relatively exceptionally poor, the maximax decision rule will not be able to take it into account. Thus if the inability to account for a relatively exceptionally poor criterion measure is not a critical issue if there exists a relatively exceptionally good criterion measure, the use of the maximax decision rule is justifiable.

3.5.3.2 Maximin Decision Rule

The minimum weighted value of the criteria, $WVUC_3^{MIN}$ is the second parameter that results from the "ranking of the criteria" analysis. The maximin decision rule is the one that uses $WVUC_3^{MIN}$ as the decision variable. Thus for each project:

$$WVUC_3^{MIN} = MIN \left[\sum_{j=1}^{i} \frac{u(x_j)}{i} \right]$$

$$i = 1,2....m$$

The use of this decision rule contrary to the maximax decision rule is of a "more conservative" nature. The occurrence of a relatively exceptionally poor criterion measure is taken into account by this decision rule. On the other hand this decision rule is unable to reflect the occurrence of a relatively exceptionally good criterion measure. Thus if the ability to account for a relatively exceptionally poor criterion measure is critical as illustrated by the analogy of "a chain is as strong as its weakest link," then the use of the maximin criteria measure is justifiable.

3.5.3.3 A Summary

The properties of the maximax decision rule and the maximin decision rule have been briefly delineated. The maximax decision rule has been outlined as a less conservative approach while the maximin decision rule has been outlined as a more conservative approach.

In summary then the question of which decision rule is appropriate is dependent on the specific preference and environment of different situations. The understanding of the implications of the two decision rule is critical to their appropriate implementation.

CHAPTER 4: A CASE STUDY

The basic layout of the conceptual framework for the multi-criteria appraisal of feeder road projects is presented in Chapter 3. In the present chapter, a case study is structured to illustrate the implementation of the methodology. It must be stressed that the case study here represents just one possible scenario, and that the appraisal methodology is applicable in various other possible scenarios as well.

4.1 THE IDENTIFICATION OF PROJECTS

As was stated earlier, the identification of projects is a very important first step in the project cycle. In our simplified interpretation, it is part of the design problem but, nevertheless, is an extremely important part of the entire cycle because the quality of the projects selected is dependent on adequate and sufficient identification of potential projects. In other words, the projects selected will only be as good as the best of the projects available for selection.

Israel (1970) identifies four tasks as constituting the identification stage:

(1) A regional development strategy has to be formulated for the objectives of the development effort.

(2) The important potential constraints or barriers (social, economic and institutional) hindering the achievement of the above objectives need to be identified.

(3) The barriers remaining over the planning period for any conceivable reason need to be singled out.

(4) The planning and implementation of appropriate policy actions or of specific investment projects or in some instances both enabling the elimination of each barrier or constraint on the development effort are needed.

Table 4-1 shows the nature of the contents of a regional survey in the identification stage and illustrates some possible corrective actions for the potential barriers to the rural development effort.

4.2 DESCRIPTION OF THE PROJECTS

4.2.1 A Detailed Description of One Project

In this section a detailed description of one of the projects, the Makir-Aros* feeder road project (Figure 4-1), is presented. It must be noted, however, that this is not a typical feeder road project but just one of the myriad of possible scenarios. A brief description of the overall set of projects which is to be ranked and some of the differences among the projects is given in Section 4.2.2.

The proposed 20 kilometers feeder road project extends out from a small provincial market town of Makir. The community of Aros served by the road has suitable conditions (physical, ecological, demographic, etc.) for agricultural development. At present a trail (earth road not passable by motor vehicles) exists which is mainly used for walking or transport by pack animals to the market town where the peasants periodically come to sell some of their agricultural surplus or to buy some consumer goods (cloth, spices, etc.).

As part of a regional development effort, this project has been identified and a proposed package of investment projects has been advocated

*This is a hypothetical project.

TABLE 4-1: CONTENT OF REGIONAL SURVEY IN THE IDENTIFICATION STAGE

Domain	Potential barriers to rural development	Potential corrective action
1. Resource base (minerals, soils, vegetation, energy sources)	Extreme scarcity of one or more resources.	Investment to improve the quality of existing resources (fertilizer plants, power plants)
2. Population and Health	Overpopulation Underpopulation Malnutrition Low health standards	Labor intensive projects Migration policies Food production Health investments
3. Educational levels	Illiteracy Lack of skilled labor	Education investments Migration policies
4. Infrastructure	Lack of infrastructure	Transport projects Irrigation projects Power projects
5. Productive structure	Inadequate and traditional production techniques Lack of supporting activities (marketing boards, banks)	Investments in new productive activities Institutional changes Extension services Credit services
6. Demand conditions	Insufficient demand	Export-oriented industries
7. Market system	Monopolistic markets	Institutional changes
8. Response to past incentives	Lack of response	Extension services Institutional changes Education investments

Source: Arturo Israel, "Appraisal Methodology for Feeder Road Projects".

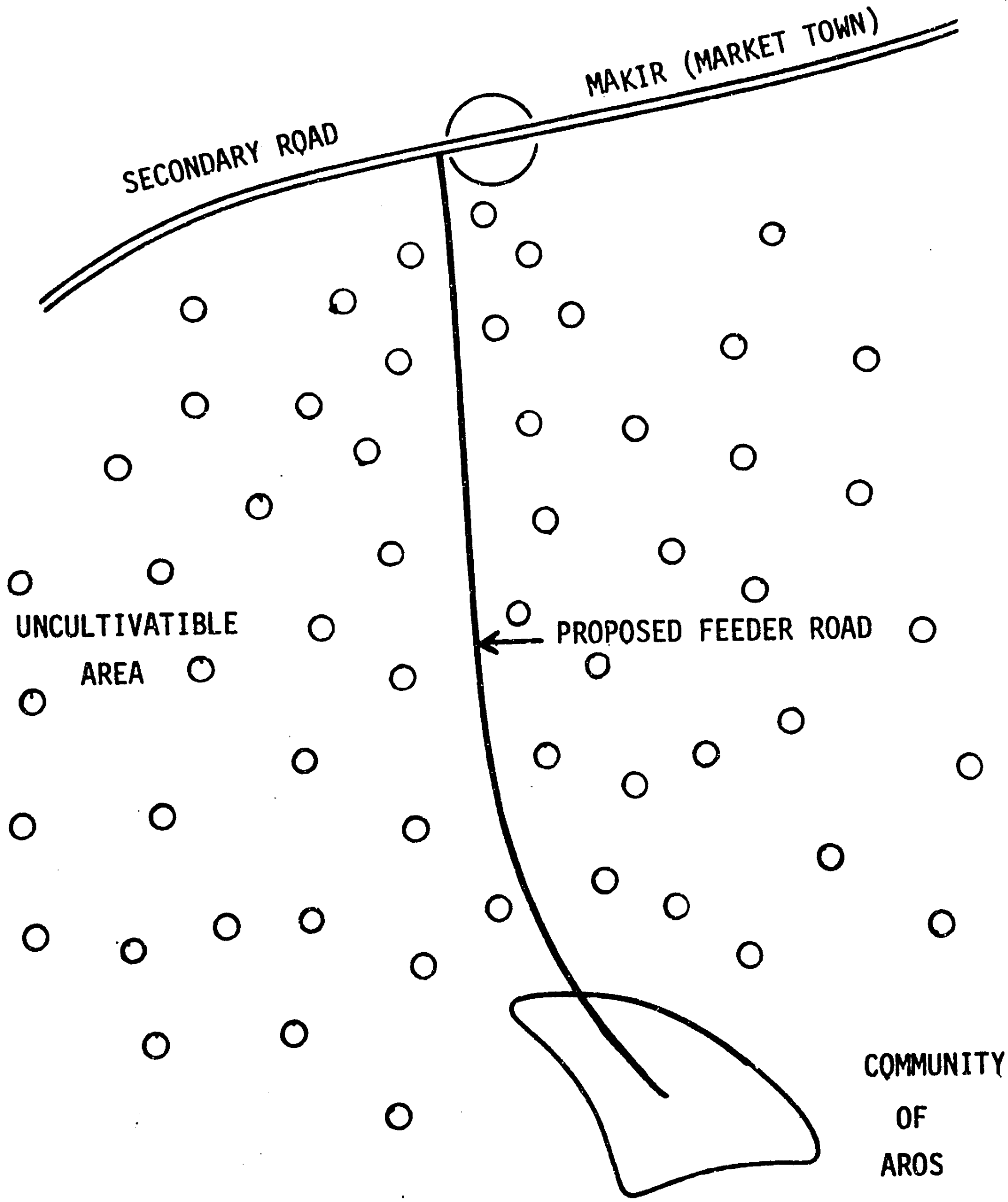

FIGURE 4-1: ILLUSTRATION OF THE PROJECT AREA

by the design team, consisting of a gravel road, extension services and help to grow some new crops, a new health clinic in the community of Aros, and provision of some general education for both adults and children.

4.2.1.1 <u>Land Ownership Pattern</u>

The community of Aros has 109 families, and the population totals about 600 persons. In a survey of the area, the population could be divided into three different groups using land ownership characteristics. There are 5 relatively rich families who own between 45 to 50 hectares of land per family. This comprises the first group. The second group, consisting of 34 families, is characterized by the ownership of 2 to 10 hectares of land per family. The third group, totalling about 70 families, is characterized by being landless. They can be further subdivided into two groups. One group, numbering 50 families, rents a total of about 100 hectares from the relatively richer families for subsistence farming. They pay the landlords with some of their agricultural produce and occasionally with some services. The other 20 families are directly under the "umbrella" of the relatively richer group and do not farm any land of their own. They work for the relatively richer families and in return receive some subsistence wage mostly in kind.

4.2.1.2 <u>Agricultural Activities before the Project</u>

Presently the agricultural production consists mostly of cassava, some rice and some maize with a bit of livestock. The relatively richer families and some of the small land owners have some agricultural surplus which they carry by pack animals or even on their heads to the market town of Makir which is served by a good secondary road.

Table 4-2 shows the quantity of land under the 3 crops, the average yields and the market value of the present agricultural production. Figure 4-2 summarizes the present distribution and type of agricultural activity.

4.2.1.3 Agricultural Activities Planned for the Project

It is planned to introduce new varieties of seeds and the use of fertilizers for the crops of cassava, maize and rice. The proper cultivation of the new varieties with the essential assistance and direction of the proposed extension staff will result in substantial increase in yield.

There is at present a total of 113 hectares of cultivatible land which is presently uncultivated and idle. The proposed plan is to induce the owners of this land to plant cash crops of cocoa which is highly suitable to the climatic and soil conditions of these 113 hectares of as yet uncultivated land. Cocoa is highly profitable and commands a good price with a high demand as an export commodity.

Adjacent to the community is a parcel of government land which is covered with secondary forests but has good soil for the cultivation of cocoa. It is planned to clear this parcel to enable the 70 landless families to cultivate these parcels of land. The 70 landless families will be granted a hectare each and the necessary credit (payable in easy installments when the land pays off) provided to help them have a chance to have a better life.

4.2.1.4 The Appraisal Report

The appraisal team has to prepare the necessary information to include

TABLE 4-2:

PRESENT AGRICULTURAL ACTIVITIES

Crop	# Hectares	Yield/ Hectare	Market Price	Value
Cassava	250	2000 lb	P0.25/lb	P125000
Rice	80	3250 lb	P0.50/lb	P130000
Maize	75	2020 lb	P0.70/lb	P106050
Total	405			P361050

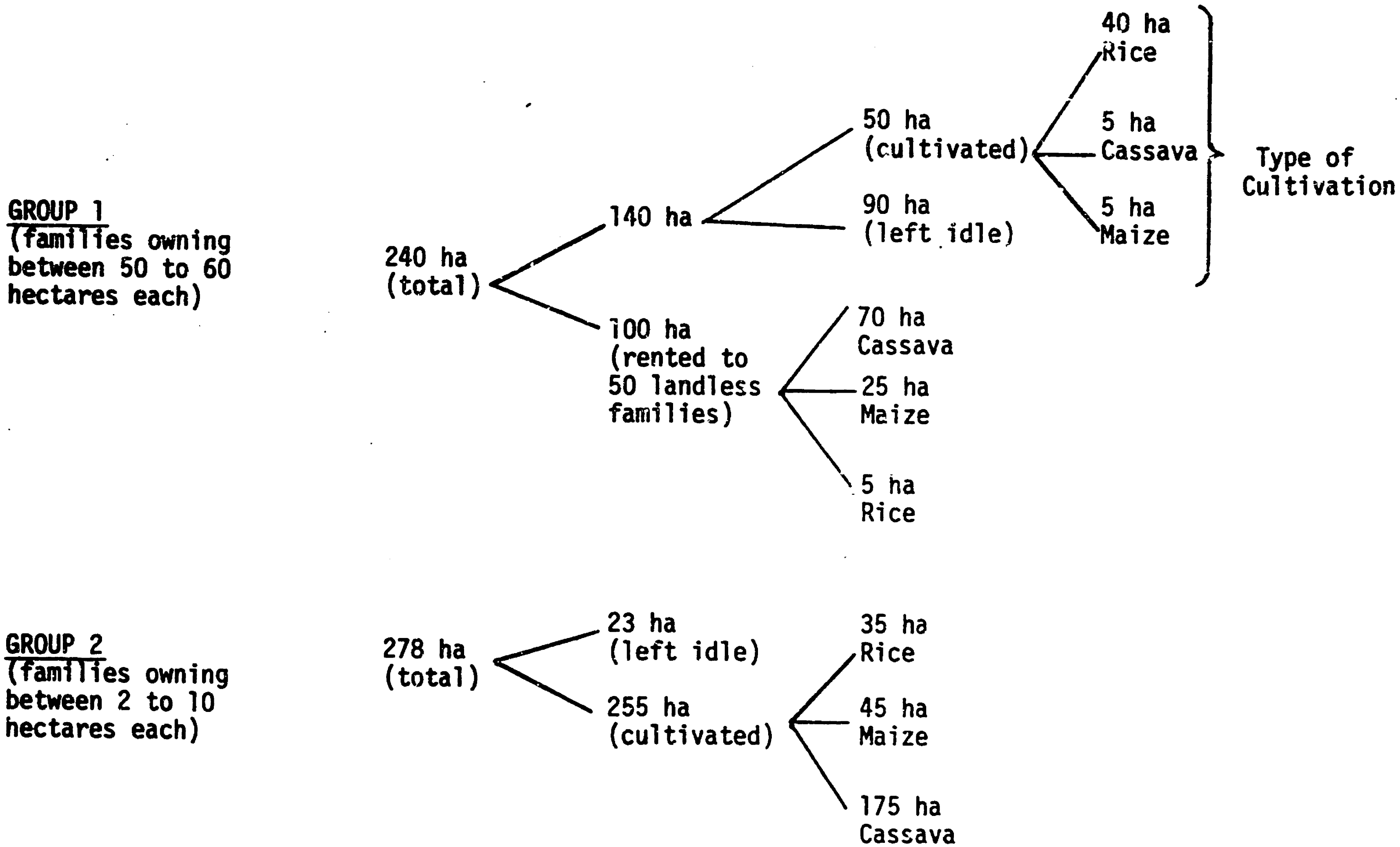

FIGURE 4-2: SUMMARY OF PRESENT DISTRIBUTION AND TYPE OF AGRICULTURAL ACTIVITY

this project for selection. The appraisal criteria consist of economic, distribution, accessibility to social services and employment.

The benefits accruing to the criteria under consideration are discussed under the stipulation that the contributions are as a result of the provision of the feeder road. Each of them will be elaborated in turn.

The contribution to the economic benefits measure is in the form of induced agricultural production. The prediction of this is of course difficult in practice and there have been many instances where it has been overestimated to make the IRR look acceptable. There are many factors that will have an influence on how much induced agricultural production will actually be realized. Basically the provision of the road will provide a reliable access for the marketing of agriculture produce. It will provide easier access for possible introduction of new technology and inputs and allow the coming of government extension workers. This extension help might range from introduction of new technologies and inputs for better agricultural productivity to just simply education to improve utilization of existing facilities.

However, the final prediction of how much induced agricultural production will be realized will depend on how receptive the farmers are to the introduction of the new ideas, the availability of cultivatable land and adequate climatic and water requirements, the existence of a market for the produce, the existence of sufficiently attractive farmgate prices to provide adequate financial incentives to the farmer, the availability of sufficient labor and capital (animals, money for inputs, etc.), and so forth. These are but some of the social, institutional and economic constraints which will have a great effect on the magnitude of the induced economic activity.

There are two possible ways to take these factors into consideration in making the predictions for the purpose of appraisal. One is the development of disaggregate behavioral models* which incorporates these factors as independent causal variables. Alternatively the prediction of the induced economic activity can be performed by a team of interdisciplinary "experts" consisting of agricultural economists, sociologists, engineers and maybe even an anthropologist.

The choice of the strategy to adopt depends on the biases of the individual decision making authority and the availability of data. In this particular case, the road authority has opted for the use of the interdisciplinary team of experts; the team consists of an agriculturalist with a working knowledge of economics, an engineer and a social anthropologist. The appraisal team has studied the area and the plans of the project. Their analysis yields the measures to the various criteria of interest.

4.2.1.4.1 Economic Benefits Measure

The measure of the economic benefits is the difference in the present value of the expected value of the agricultural activity with the implementation of the project with that of the no-project alternative. The technique that will be used to predict the agricultural activity is the assessment of the project by an interdisciplinary appraisal team.

Table 4-3 shows the results of the assessment of the appraisal team

*There is a discussion of the merits of different modelling approaches in Section 2.3.

TABLE 4-3: ASSESSMENT OF THE APPRAISAL TEAM ON THE PR (NEW CULTIVATION)

Type of Crop	Rice			Cocoa				Cassava			Maize		
Group	1	2	3a	1	2	3a	3b	1	2	3a	1	2	3a
Year													
0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0.8	0.6	0.5	.9	.6	.7	.4	1.0	.3	.2	1.0	.3	.2
2	0.9	0.6	0.5	.9	.6	.7	.4	1.0	.3	.2	1.0	.3	.3
3	0.9	0.7	0.5	1.0	.6	.8	.5	1.0	.4	.3	1.0	.4	.3
4	0.9	0.7	0.6	1.0	.8	.8	.5	1.0	.4	.3	1.0	.4	.4
5	1.0	0.8	0.6	1.0	.9	.9	.5	1.0	.5	.4	1.0	.5	.5
6	1.0	0.8	0.6	1.0	1.0	1.0	.6	1.0	.8	.5	1.0	.8	.7
7	1.0	0.8	0.8	1.0	1.0	1.0	.7	1.0	.9	.7	1.0	.9	.8
8	1.0	0.9	0.9	1.0	1.0	1.0	.8	1.0	1.0	.8	1.0	1.0	1.0
9	1.0	1.0	1.0	1.0	1.0	1.0	.9	1.0	1.0	1.0	1.0	1.0	1.0
10	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
11	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
12	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

on the probability that the new cultivation will be carried out by the various groups for the four crops over the project life.

The expected average yields per hectare for each of the crops are detailed in Table 4-4. The expected value of agricultural production with the implementation of the project is detailed in Table 4-5. The figures are obtained from calculations that are illustrated in Tables 4-6, 4-7, 4-8 and 4-9 for each particular crop and a particular year.

Table 4-10, in turn, details the calculation for the expected value of agricultural production without the project.

The measure that comes out from this analysis is the net expected present value of agricultural activity:

$$\text{NEPV} = \begin{bmatrix}\text{Present value of} \\ \text{agriculture production} \\ \text{with the project.}\end{bmatrix} - \begin{bmatrix}\text{Present value of} \\ \text{agriculture} \\ \text{production without} \\ \text{the project.}\end{bmatrix}$$

$$= \text{P } 7{,}603{,}868 - \text{P } 3{,}258{,}190^{*}$$

$$= \text{P } 4{,}345{,}678$$

4.2.1.4.2 <u>Economic Costs Measure</u>

Table 4-11 shows a summary of the stream of expenditures that make up the project costs. Briefly, the items of expenditure include everything that is considered as part of the project. These include all expenditure items related to the construction and maintenance of the road, the costs of building and staffing the health clinic, the costs of the provision of general education and the costs related to the introduction of better inputs for the agricultural activities (extension workers, seeds, etc.).

*These are discounted at 8%

TABLE 4-4:

EXPECTED AVERAGE YIELDS PER HECTARE

Year	Cassava (lb)	Rice (lb)	Cocoa (lb)	Maize (lb)
0	2000	3250	0	2020
1	2200	3500	0	2200
2	2400	4000	0	2400
3	2600	5000	0	2600
4	2800	5500	2800	2600
5	3000	5750	2800	2600
6	3300	5750	3000	2800
7	3500	6000	3000	3000
8	3500	6000	3000	3200
9	3500	6000	3000	3200
10	3500	6000	3000	3200
11	3500	6000	3000	3200
12	3500	6000	3000	3200

TABLE 4-5:

EXPECTED VALUE OF AGRICULTURAL PRODUCTION WITH THE PROJECT

Year	Rice	Cocoa	Cassava	Maize
0	130000	0	125000	106050
1	136938	0	128575	109011
2	152313	0	132150	112966
3	185125	0	139400	118433
4	201438	559468	144200	119448
5	218750	559468	155125	122290
6	218750	669030	183500	137991
7	229000	689040	204313	150983
8	234500	720795	213500	168000
9	240000	761250	218750	168000
10	240000	769950	218750	168000
11	240000	778650	218750	168000
12	240000	787350	218750	168000

Present value at 8% = P7,603,868

TABLE 4-6:

ASSESSMENT OF AGRICULTURAL PRODUCTION

TYPE OF CROP: RICE

YEAR: 4

Type of Group	Cultivatible Areas A	"Old"* Average Yield Y_o	"New"** Average Yield Y_1	Predicted Average Unit Market Price P_1	FROR*** to Farmer	Demand Conditions	Other Relevant Parameters	Subjective**** Assessment of Pr [cultivation] Pr	Expected Value $[Pr x P_1 x Y_1 x A + (1 - Pr x P_1 x Y_o x A]$
1	40	3250 lb/ha.	5500 lb/ha.	P 0.5	50%	Excellent	Survey indicates good response	0.9	P105500
2	35	3250 lb/ha.	5500 lb/ha.	P 0.5	50%	Excellent	From survey it seems some farmers exhi[illegible] risk aversion to the changeover	0.7	P84438
3a	5	3250 lb/ha.	5500 lb/ha.	P 0.5	50%	Excellent	High risk aversion to change in new seed varieties	0.6	P11500

*From Table 4-2
**From Table 4-4
***Financial rate of return
****From Table 4-3

TABLE 4-7:

ASSESSMENT OF AGRICULTURAL PRODUCTION

TYPE OF CROP: COCOA

YEAR: 4

Type of Crop	Cultivatible Areas A	"Old"* Average Yield Y_o	"New"** Average Yield Y_1	Predicted Average Unit Market Price P_1	FROR*** to Farmer	Demand Conditions	Other Relevant Parameters	Subjective**** Assessment of Pr [cultivation] Pr	Expected Value $[Pr \times P_1 \times Y_1 \times A + (1-Pr) \times P_1 \times Y_o \times A]$
1	90		2800 lb/ha.	P 1.45	60%	Excellent, the Cocoa can be sold to buyers in Makir and there is an excellent demand for it as an export commodity.	There is a gestation period of four years before benefits are realized. This is a new crop.	0.9	P328860
2	23		2800 lb/ha.	P 1.45	60%			0.6	P56028
3a	50		2800 lb/ha.	P 1.45	60%			0.7	P142100
3b	20		2800 lb/ha.	P 1.45	60%			0.4	P32480

*From Table 4-2
**From Table 4-4
***Financial rate of return
****From Table 4-3

TABLE 4-8:

ASSESSMENT OF AGRICULTURAL PRODUCTION

TYPE OF CROP: CASSAVA

YEAR: 7

Type of Group	Cultivatible Areas A	"Old"* Average Yield Y_o	"New"** Average Yield Y_1	Predicted Average Unit Market Price P_1	FROR*** to Farmer	Demand Conditions	Other Relevant Parameters	Subjective**** Assessment of Pr [cultivation] Pr	Expected Value $[Pr \times P_1 \times Y_1 \times A + (1-Pr) \times P_1 \times Y_o \times A]$
1	5	2000 lb/ha.	3500 lb/ha.	P 0.25	45%	Excellent	By now the farmers have realized that the introduction of the new inputs are very profitable as demonstrated by the entrepreneurship of the richer farmers	1.0	P4375
2	175	2000 lb/ha.	3500 lb/ha.	P 0.25	45%	Excellent		0.9	P146563
3a	70	2000 lb/ha.	3500 lb/ha.	P 0.25	45%	Excellent		0.7	P53375

*From Table 4-2
**From Table 4-4
***Financial rate of return
****From Table 4-3

TABLE 4-9:

ASSESSMENT OF AGRICULTURAL PRODUCTION

TYPE OF CROP: MAIZE YEAR: 1

Type of Group	Cultivatible Areas A	"Old"* Average Yield Y_0	"New"** Average Yield Y_1	Predicted Average Unit Market Price P_1	FROR*** to Farmer	Demand Conditions	Other Relevant Parameters	Subjective**** Assessment of Pr [cultivation] Pr	Expected Value $[Pr \times P_1 \times Y_1 \times A + (1-Pr) \times P_1 \times Y_0 \times A]$
1	5	2020 lb/ha.	2200 lb/ha.	P 0.7	32%	Good price exists for maize and demand for it is good.	Only the Group 1 Farmer will "gamble" on the new cultivation while the majority of the other 2 groups will not dare take the risk.	1.0	P7700
2	45	2020 lb/ha.	2200 lb/ha.	P 0.7	32%			0.3	P68331
3a	25	2020 lb/ha.	2200 lb/ha.	P 0.7	32%			0.2	P35980

*From Table 4-2
**From Table 4-4
***Financial rate of return
****From Table 4-3

TABLE 4-10

EXPECTED VALUE OF AGRICULTURAL PRODUCTION WITHOUT THE PROJECT

Year	Rice	Cassava	Maize
0	P 130000	P 125000	P 106050
1	P 130000	P 125000	P 106050
2	P 130000	P 125000	P 106050
3	P 130000	P 125000	P 106050
4	P 130000	P 125000	P 106050
5	P 143000	P 125000	P 106050
6	P 143000	P 125000	P 106050
7	P 143000	P 125000	P 106050
8	P 143000	P 125000	P 106050
9	P 156000	P 125000	P 121958
10	P 156000	P 125000	P 121958
11	P 156000	P 125000	P 121958
12	P 156000	P 125000	P 121958

Present Value at 8% = P 3,258,190

TABLE 4-11

STREAM OF PROJECT EXPENDITURES

Year	Project Expenditures
0	P 170,000
1	P 310,000
2	P 300,000
3	P 350,000
4	P 100,000
5	P 90,000
6	P 60,000
7	P 60,000
8	P 60,000
9	P 50,000
10	P 40,000
11	P 20,000
12	P 20,000

Present value at 8% = P 1,292,130

4.2.1.4.3 Distribution Measure

The measure of the distribution of the economic benefits has been discussed in Chapter 3 and the use of the proxy of land-ownership by the target income group of interest was advocated. It is recognized that this proxy measure is not perfect, but the relative ease with which it can be measured makes it a highly attractive choice. The restrictive assumptions that need to be made to make this a valid measure are:

(1) The cultivatible land owned by the target group is in general less than 10 hectares per family.

(2) Economic conditions of perfect competition exist.

(3) Average productivity of land is uniform.

(4) The share of economic benefits is proportional to land ownership.

In this particular project, the number of families belonging to the target group of interest number about 104 families. In fact, all the families in the project area except for the five relatively richer families qualify for consideration in this case. The projected area of cultivatible land that will be under the ownership of these 104 families totals 348 hectares. These include the 278 hectares owned by families classified as group 2 and the seventy hectares of government land (one hectare per family) that will be provided to the seventy landless families (group 3a and 3b).

4.2.1.4.4 Accessibility to Social Services Measure

At the present moment, the community of Aros enjoys the health services of local midwives. As a consequence of the implementation of the project, the people will have the services of a health clinic which will be built in the community. Thus the accessibility to health services will have a measure of:

$$\begin{bmatrix}\text{score of the change*}\\ \text{in health services}\end{bmatrix} \times \begin{bmatrix}\text{population served}\end{bmatrix}$$

$= 10 \times 600$

$= 6000$

In terms of accessibility to educational facilities, the community will enjoy an initial change from nothing to some general education which will be provided to the younger population of the community. Thus the accessibility to education services will have a measure of:

$$\begin{bmatrix}\text{score of the change in}\\ \text{education facilities}\end{bmatrix} \times \begin{bmatrix}\text{population served}\end{bmatrix}$$

$= 3 \times 162$

$= 486$

Finally, the measure of the accessibility to social services is the sum of the two measures of accessibility to health services and accessibility to educational facilities. For this project this measure equals 6000 + 486 = 6486 ATSS units.

4.2.1.4.5 Employment Measure

The employment that is generated or is a consequence of the implementation of the project arises from that of the construction period of 30 months and the increased agricultural activity over the project life. The

*See Table 3-2, page

employment of the extension workers and other government employees will not be counted because if they were not used in this project they would presumably be employed elsewhere. Thus the employment measure is primarily concerned with accounting for the mobilization of the local factors of production, the rural peasant labor.

The project documents indicate a total of 83,050 man-days of employment is generated as a direct consequence of the construction and maintenance activities.

For the cocoa cultivation, the agriculturalist indicated that an average of 180 man-days per year of employment will be generated per hectare of cocoa cultivation. From the information generated by the appraisal team (Tables 4-2, 4-3), it can be calculated that the expected total annual-area of cocoa cultivation over the project life amounts to 2,014.5 hectares. Correspondingly, the employment generated by cocoa cultivation totals 362,610 man-days.

For the rice cultivation, the agriculturalist indicated that the introduction of the new inputs and cultivation methods will yield an increment of 55 man-days per year for each hectare of transformed rice cultivation. The expected total annual-area of transformed cultivation calculated from Tables 4-2 and 4-3 equals 855 hectares. Consequently, the employment generated by cocoa cultivation totals 47,025 man-days.

For the cassava cultivation, the increment in employment as a consequence of the changeover in agricultural technology equals 39 man-days per year per hectare. The expected total annual-area of transformed cultivation calculated from Tables 4-2, 4-3 equals 2,083 hectares. Thus the employment generated from cassava cultivation amounts to 81,237 man-days.

The increment in employment for the transformed maize cultivation is 27 man-days per year per hectare. As 652 hectares is the expected total annual-area of transformed cultivation calculated from Tables 4-2, 4-3 the resulting employment generated is 17,604 man-days.

Finally, the total employment generated as a direct consequence of the project is:

$$\begin{bmatrix}\text{Construction-generated}\\ \text{employment}\end{bmatrix} + \begin{bmatrix}\text{Rice cultivation-}\\ \text{generated employment}\end{bmatrix} + \begin{bmatrix}\text{Cocoa-cultivation-}\\ \text{generated employment}\end{bmatrix}$$

$$+ \begin{bmatrix}\text{Cassava cultivation-}\\ \text{generated employment}\end{bmatrix} + \begin{bmatrix}\text{Maize cultivation-}\\ \text{generated employment}\end{bmatrix}$$

$$= 83{,}050 + 47{,}025 + 362{,}610 + 81{,}237 + 17{,}604$$

$$= 591{,}526 \text{ man-days}$$

4.2.2. A General Description of all the Projects

In the previous section a detailed description of a single project was presented. A total of 36 projects have been identified and prepared; their appraisal measures are presented in Table 4-12. Each project has five measures and each of these measures is denominated in its own unit of measure.

The economic benefits measure is represented by the difference in the expected present value of agricultural activity with the project with the expected present value of agricultural activity without the project. The economic costs criteria is represented by the present value of all the relevant project expenditure items. The distribution measure is captured by the ownership of land in hectares by the target group of

TABLE 4-12 SUMMARY OF THE CRITERIA MEASURES FOR ALL THE PROJECTS

Project Number	Economic Benefits	Economic Costs	Distribution (Hectares)	Employment (Man-Days)	Accessibility (ATSS Units)
1	4345678	1292130	348	591526	6846
2	3943230	2864390	623	700105#	8324
3	2432100	2032000	326	200010	5324
4	9008000#	2324430	20*	356320	3234
5	8432432	1101368	35	253436	1634
6	7436562	1343520	39	275343	2398
7	5100000	1400362	421	623431	5002
8	4400320	968400	521	532432	4326
9	2960860	940500	631	361432	2498
10	1960000	932632	720	213432	5142
11	3943200	1010060	203	349946	3924
12	4900632	1326360	196	436248	3062
13	5100656	2010612	800	632160	11432
14	4562020	2306542	953	639196	12530
15	3862062	1743680	732	432960	8410
16	7632952	1560000	621	395432	6458
17	7800432	3400738	432	296050	4322
18	2860432	708680	205	543200	1900
19	1143620	693620	103	132000*	820
20	800632*	620632*	190	140000	0*
21	5432620	900632	25	290000	2320
22	3960462	1152120	1000#	360000	4324
23	6832420	3500000#	612	496000	7234
24	5823400	3010000	528	430000	13000#
25	3000620	1500060	700	180000	2848
26	3400621	1200362	420	362620	3620
27	6236520	2003620	600	490000	6200
28	3900000	2400000	800	450000	8200
29	1500000	1200000	862	290000	4320
30	2190000	1500000	622	320000	7000
31	6620000	1600000	523	420000	7200
32	4702620	2010320	502	580000	8206
33	4230060	3206820	202	362000	9200
34	3630000	1100000	392	392000	1020
35	4000000	2163000	252	432000	7260
36	4526387	2456700	159	362140	6588

* Lowest
# Highest

interest. The employment measure is represented by the amount of employment in the construction and agricultural activities generated by the project. Finally the accessibility to social services measure is represented by the score in ATSS units resulting from the change in accessibility to the services of health and education as a consequence of the project.

There is a great variation in the contributions to the five criteria for the thirty six projects. No pattern can be used to point out these differences as they depend on the specific circumstances of each particular project. As an extreme example, any project may have the best contribution with respect to one criterion, but at the same time may have the worst contribution with respect to another criterion. Project 4 has the characteristics just described. It has the best contribution with respect to the economic benefits measure (P9,008,000), but on the other hand, it has the worst contribution with respect to the distribution criteria (20 hectares). This is an example of a situation where the land, in the project area of influence, is owned by rich landlords who will be able to take advantage of the transport improvement, resulting in high economic benefits in the form of induced agricultural production but low distribution effects in the sense that the poorer farmers will only reap an insignificant amount of the economic benefits.

The other variations in the criteria among all the projects can also be interpreted in an analogous fashion. However, the interpretation will have to be made with respect to the different contexts involved and the resulting different implications.

4.3 DETERMINATION OF THE INDIVIDUAL CRITERION PREFERENCE FUNCTION

The various techniques that can be used to assess the individual criterion preference (or utility) function have been discussed in Section 3.4 . The technique to be used depends on the type of multicriteria problem encountered and the preferences of the decision-maker. Nevertheless the proper education and familiarization of the decision-maker with the technique used cannot be overemphasized.

In the present case, the direct method has been chosen as the assessment technique. For each criteria, the lowest to the highest attainment from all the projects under consideration are put on the horizontal axis. Along the vertical axis is a common scale of from 0 to 100. The lowest attainment is assigned the value of 0, while the highest attainment is assigned the value of 100. The exception is the economic costs criteria whereby the lowest attainment is assigned a value of 100 and the highest attainment is assigned a value of 0. The decision-maker is asked to articulate an approximate value of the measure which corresponds to 50 (midway) on the scale. This is repeated for the 2 mid-points: one between 0 and 50 (25) and the other between 50 and 100 (75).

The articulation of these three points by the decision-maker enables the analyst to arrive at approximate but appropriate preference functions for each of the five criteria. If more refined functions are required more points may be elicited in this similar manner. But often the elicitation of just these three approximate points will suffice for a good fit of the form of the preference function.

4.3.1 Economic Benefits Preference Function

The measure of the economic benefits of the project run from P 800,632 for project number 20 to P 9,008,000 for project number 4. The value of P 6,000,000 has been articulated as the "50" point on the scale.

The resulting economic benefits preference (utility) function (Figure 4-3) is:

$$u(x_1) = \begin{cases} 0.000009617\ x_1 - 7.699 & 800{,}632 \le x_1 \le 6{,}000{,}000 \\ 0.000015\ x_1 - 40 & 6{,}000{,}000 \le x_1 \le 9{,}008{,}000 \end{cases}$$

4.3.2 Economic Costs Preference Function

The measure of the economic costs from all the projects has the lowest value of P 620,632 and the highest value of P 3,500,000. The value of P 1,500,000 has been articulated as the "50" point and the value of P 2,600,000 as the "25" point.

Therefore, the economic costs preference (utility) function (Figure 4-4) is:

$$u(x_2) = \begin{cases} -0.000055\ x_2 + 134.135 & 620{,}632 \le x_2 \le 1{,}500{,}000 \\ -0.0000227\ x_2 + 84.05 & 1{,}500{,}000 \le x_2 \le 2{,}600{,}000 \\ -0.0000277\ x_2 + 97.02 & 2{,}600{,}000 \le x_2 \le 3{,}500{,}000 \end{cases}$$

4.3.3 Distribution Preference Function

The measure of distribution arising from all the projects under consideration ranges from 20 hectares to 1,000 hectares. 600 hectares has

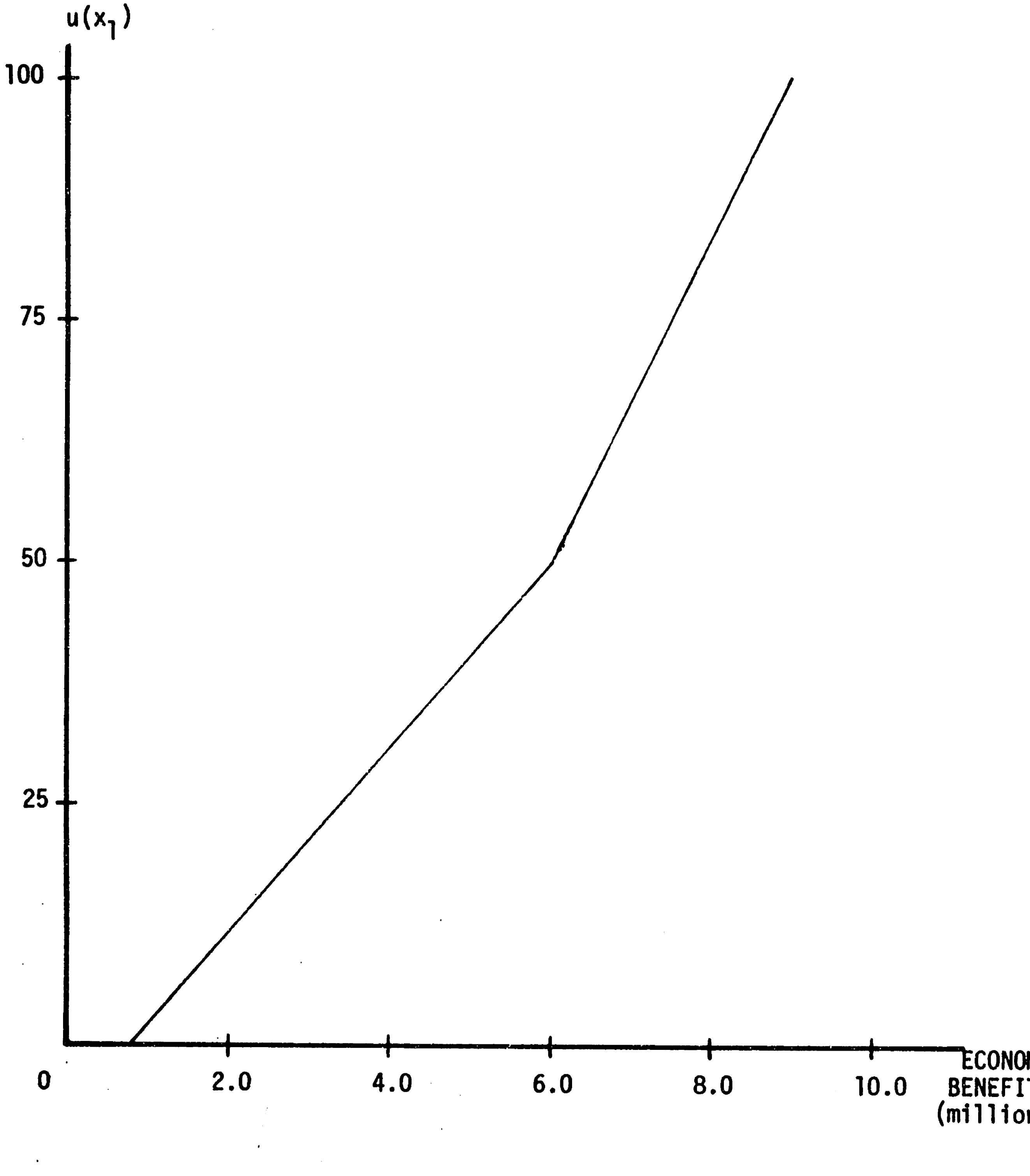

FIGURE 4-3: ECONOMIC BENEFITS PREFERENCE (UTILITY) FUNCTION

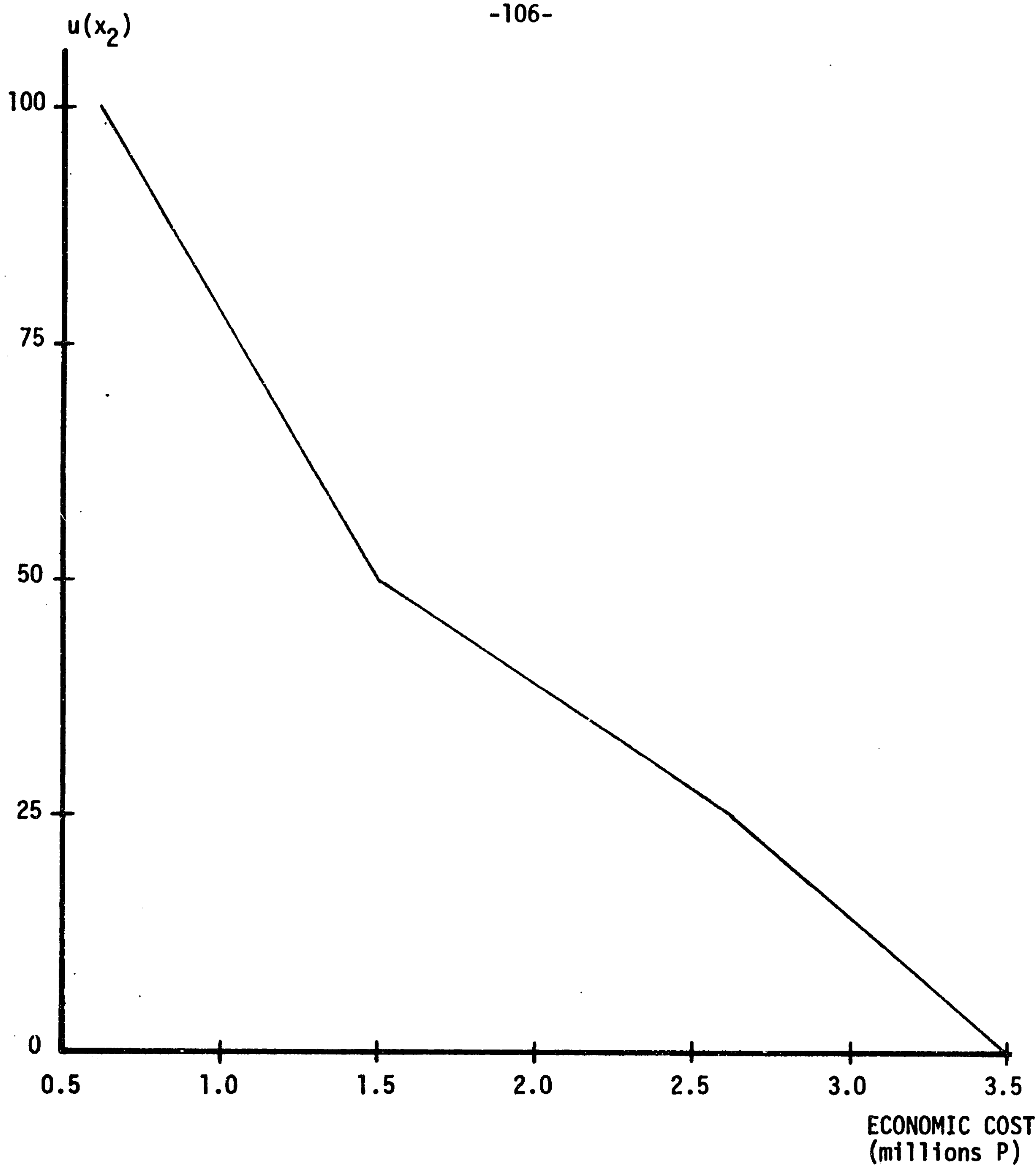

FIGURE 4-4: ECONOMIC COSTS PREFERENCE (UTILITY) FUNCTION

been articulated as the "50" point with 400 hectares as the "25" point and 720 hectares as the "75" point.

Consequently, the distribution preference function (Figure 4-5) is:

$$u(x_3) = \begin{cases} 0.0658\ x_3 - 1.316 & 20 \leq x_3 \leq 400 \\ 0.125\ x_3 - 25 & 400 \leq x_3 \leq 600 \\ 0.208\ x_3 - 75 & 600 \leq x_3 \leq 720 \\ 0.0893\ x_3 - 10.7 & 720 \leq x_3 \leq 1{,}000 \end{cases}$$

4.3.4 Employment Preference Function

The contribution to the employment measure ranges from 132,000 man-days to 700,105 man-days. 380,000 man-days is the articulated "50" point.

The employment preference function (Figure 4-6) is:

$$u(x_4) = \begin{cases} 0.0002\ x_4 - 26.4 & 132{,}000 \leq x_4 \leq 380{,}000 \\ 0.000155\ x_4 - 8.9 & 380{,}000 \leq x_4 \leq 700{,}105 \end{cases}$$

4.3.5 Accessibility to Social Services Function

The accessibility to social services measure ranges from 0 to 13,000 ATSS units. The "50" point has been articulated to be 8,000 ATSS units while the "25" point is 4,000 ATSS units and the "75" point is 12,000 ATSS units.

Therefore, the accessibility to social services function (Figure 4-7) is:

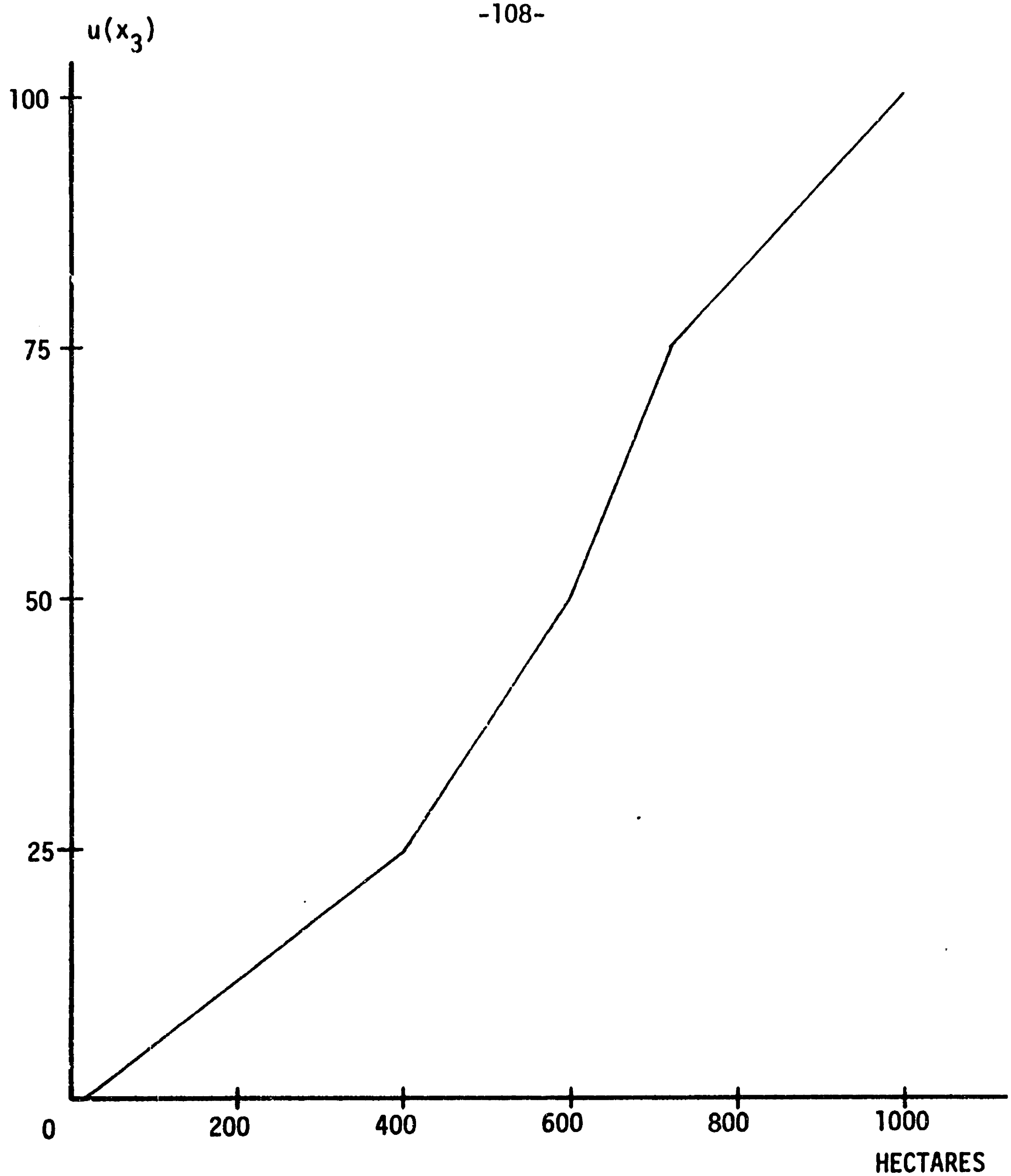

FIGURE 4-5: DISTRIBUTION PREFERENCE (UTILITY) FUNCTION

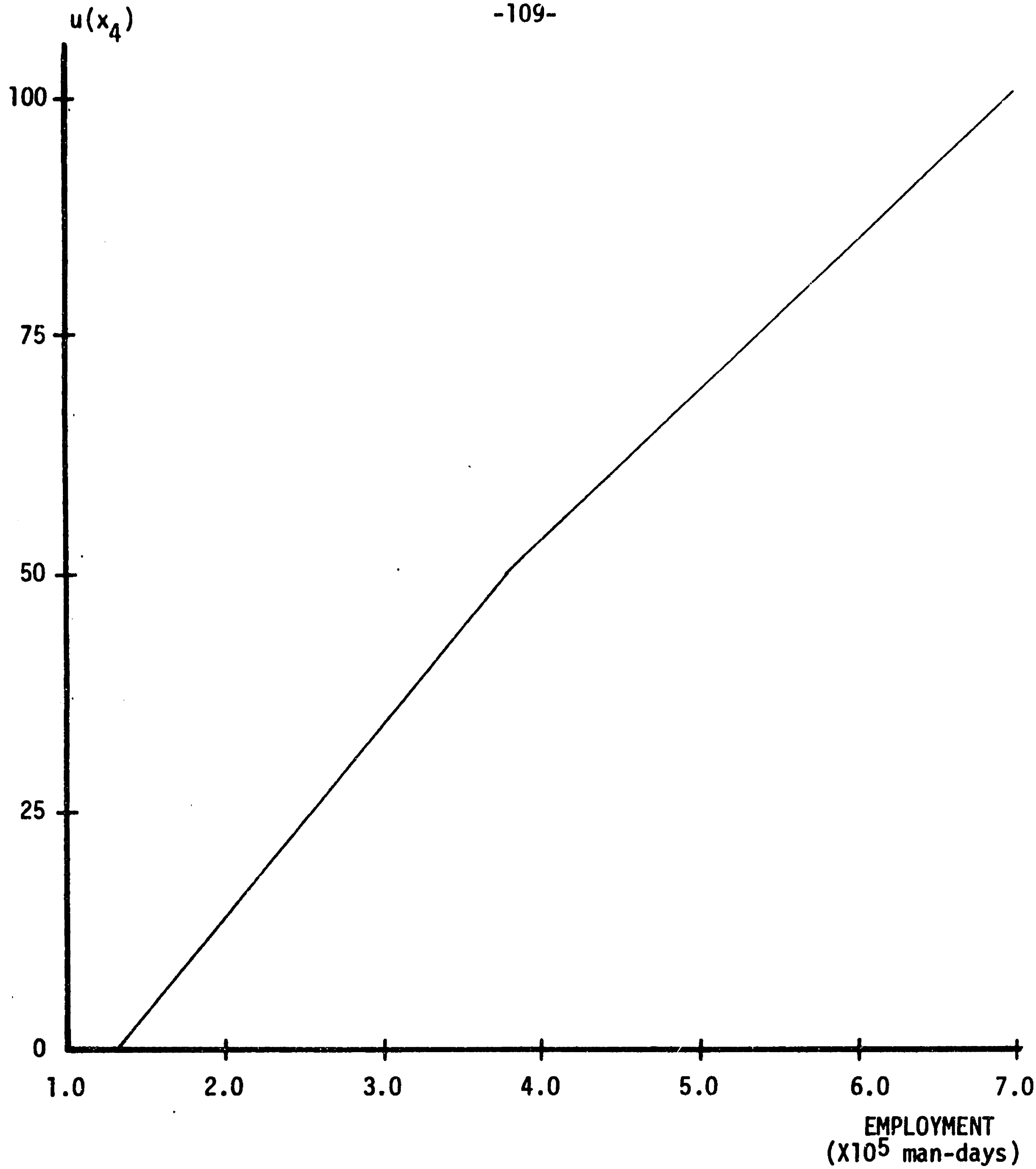

FIGURE 4-6 : EMPLOYMENT PREFERENCE (UTILITY) FUNCTION

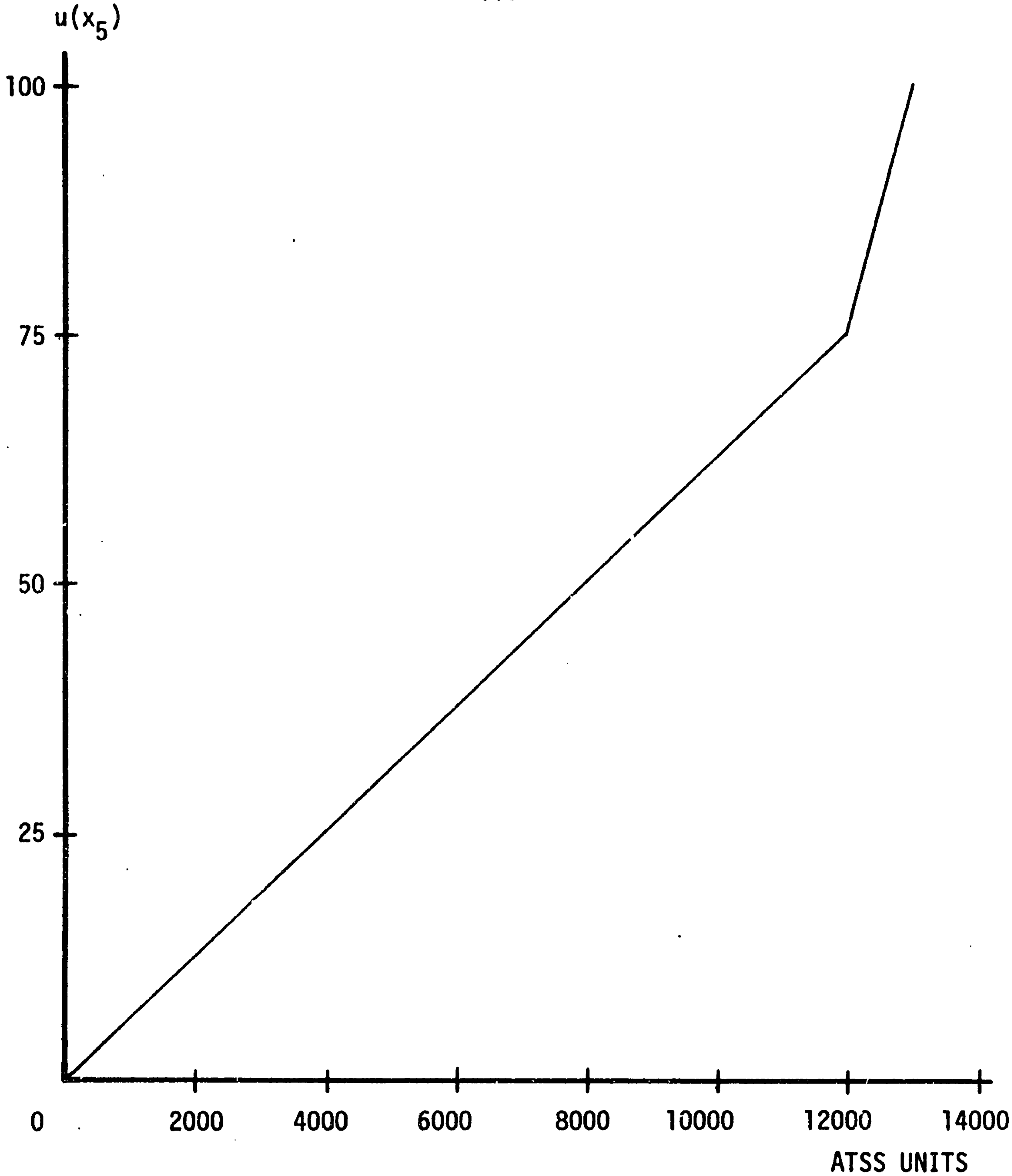

FIGURE 4-7: ACCESSIBILITY TO SOCIAL SERVICES PREFERENCE (UTILITY) FUNCTION

$$u(x_5) = \begin{cases} 0.00625\ x_5 & 0 \leq x_5 \leq 12{,}000 \\ 0.025\ x_5 - 225 & 12{,}000 \leq x_5 \leq 13{,}000 \end{cases}$$

4.4 THE SELECTION OF THE PROJECTS

To complete the analysis, that is, to combine the five criteria measures of each project into a single value structure by which the ranking of the projects can be performed, the articulation of the appropriate decision maker's value judgment is needed on the preference (weights) on each of the criteria.

In Section 3.5 three mechanisms by which the articulation of the preferences might be done were discussed, and the consequent decision rule(s) that is(are) appropriate for each of the hypotheses was(were) expounded. In the following sub-sections the results of the different decision rules are presented. The results which ensue for each decision rule are of course different because different value judgments and different amounts of information have been provided in each case. It is not possible to suggest definitely which decision rule is the "best and only one." The value judgment and amount of information that needs to be articulated for each decision rule has been discussed in Chapter 3. Thus the "appropriate" decision rule to implement is situation and case specific and is constrained by the type of value judgment that the analyst can elicit from the appropriate decision maker.

Consequently the adequate understanding by the analyst of the properties of the different decision rules is essential to the analysis. It is also the responsibility of the analyst to "educate" the decision maker on the implications of the different ways of preference articulation.

4.4.1 The Articulation of Equal Weights

When the decision maker articulates that the criteria are all equally important, it means that the weights on all the criteria are equal. If this articulation represents the "true" social preference then the analyst can proceed directly with the analysis without the need of further information from the decision maker. As discussed in Section 3.5.1 the projects can be ranked by the value of:

$$WVUC_1 = \sum_{i=1}^{5} u(x_i)$$

where $u(x_i)$ is the utility measure of criteria i.

Thus Table 4-13 shows the ranking of the 36 projects using $WVUC_1$. Projects 14 and 13 are close for the number one and two spot respectively with only about 20 units separating them. Project 14 is better than Project 13 in the third, fourth and fifth criteria while the opposite is true in terms of the first two criteria. The next two projects are project 22 and project 16 which have almost similar scores. Project 22 is separated from project 13 by a substantial difference of about 50 units. Next there is a group of 10 projects ranked from number 5 to number 14 with only about 18 units difference.

TABLE 4-13: RANKING OF THE PROJECTS USING $WVUC_1$ (EQUAL WEIGHTS)

RANK NUMBER	$WVUC_1$	PROJECT NUMBER	$u(x_1)$	$u(x_2)$	$u(x_3)$	$u(x_4)$	$u(x_5)$
1	342.38	14	36.17	31.67	95.80	90.49	88.25
2	322.73	13	41.35	38.40	82.14	89.39	71.45
3	273.16	22	30.39	69.78	100.00	45.97	27.03
4	272.93	16	77.14	48.64	54.38	52.41	40.36
5	260.81	15	29.44	44.46	76.07	58.27	52.56
6	260.72	24	48.30	13.61	41.00	57.81	100.00
7	255.81	8	34.62	80.23	40.13	73.81	27.04
8	254.69	2	30.22	17.66	54.79	100.00	52.03
9	253.68	28	29.81	29.55	82.14	60.93	51.25
10	249.66	31	60.31	47.73	40.38	56.25	45.00
11	248.42	27	53.93	38.55	50.00	67.18	38.75
12	246.20	32	37.52	38.40	37.75	81.24	51.29
13	243.92	7	41.35	55.67	27.63	88.02	31.26
14	243.32	1	34.09	61.82	21.58	83.04	42.79
15	229.67	23	63.84	0.00	52.50	68.12	45.21
16	220.91	9	20.77	81.81	56.46	46.26	15.61
17	220.32	29	6.73	67.06	87.68	31.85	27.00
18	216.96	10	11.15	82.26	75.00	16.42	32.14
19	214.34	18	19.81	94.99	12.17	75.49	11.88
20	199.60	30	13.36	50.00	54.58	37.90	43.75
21	198.78	5	90.43	72.67	0.99	24.48	10.21
22	196.70	4	100.00	31.26	0.00	45.23	20.21
23	188.80	12	39.43	59.87	11.58	58.79	19.14
24	188.66	26	25.00	67.04	27.50	46.50	22.63
25	188.58	11	30.22	77.86	12.04	43.94	24.53
26	184.46	35	30.77	34.93	15.26	58.12	45.38
27	182.68	34	27.21	72.74	24.47	51.87	6.38
28	177.91	6	73.88	58.90	1.25	28.90	14.99
29	175.31	21	44.54	84.08	0.33	31.85	14.50
30	171.77	17	79.93	2.76	29.00	33.07	27.01
31	169.47	25	21.16	50.00	70.83	9.68	17.80
32	160.80	36	35.83	28.26	9.14	46.40	41.18
33	156.97	33	32.98	8.14	11.97	46.37	57.50
34	120.72	3	15.69	37.91	20.13	13.71	33.28
35	112.80	20	0.00	100.00	11.18	1.61	0.00
36	109.73	19	3.30	95.85	5.46	0.00	5.13

4.4.2 <u>The Articulation of Cardinal Weights</u>

When the decision maker is capable and willing to articulate cardinal weights for each of the criteria, the projects can be ranked by the value of:

$$WVUC_2 = \sum_{i=1}^{5} W_i \; u(x_i)$$

where: W_i is the weight on criteria i

$u(x_i)$ is the utility measure of criteria i

The analyst will in this instance need to spend quite a bit of time with the decision maker in order that the "correct social weights" are satisfactorily articulated.

Table 4-14 shows the ranking of the 36 projects using $WVUC_2$ with:

$W_1 = 0.50$,

$W_2 = 0.20$,

$W_3 = 0.15$,

$W_4 = 0.10$ and

$W_5 = 0.05$

The first three projects (16, 5, and 4) have quite similar scores with only about 2 units difference among them. Project 4 has the lowest utility of 0 with respect to the distribution criteria, but the benefits criteria has the highest utility score of 100 which enable the $WVUC_2$ score for project 4 to rank number three since the weight on the benefits criteria is high relative to the others. The same is true for project 5 which in addition also has a high utility for the costs criteria, thus enabling it

TABLE 4-14: RANKING OF THE PROJECTS USING $WVUC_2$
(W_1=0.5, W_2=0.2, W_3=0.15, W_4=0.1, W_5=0.05)

RANK NUMBER	$WVUC_2$	PROJECT NUMBER	$u(x_1)$	$u(x_2)$	$u(x_3)$	$u(x_4)$	$u(x_5)$
1	63.71	16	77.14	48.64	54.38	52.41	40.36
2	62.86	5	90.43	72.67	0.99	24.48	10.21
3	61.79	4	100.00	31.26	0.00	45.23	20.21
4	53.63	31	60.31	47.73	40.38	56.25	45.00
5	53.19	13	41.35	38.40	82.14	89.39	71.45
6	52.55	6	73.88	58.90	1.25	28.90	14.99
7	52.25	14	36.17	31.67	95.80	90.49	88.25
8	50.83	27	53.93	38.55	50.00	67.18	38.75
9	50.10	22	30.39	69.78	100.00	45.97	27.03
10	49.52	17	79.93	2.76	29.00	33.07	27.01
11	48.87	23	63.84	0.00	52.50	68.12	45.21
12	48.11	8	34.62	80.23	40.13	73.81	27.04
13	46.31	7	41.35	55.67	27.63	88.02	31.26
14	43.80	24	48.30	13.61	41.00	57.81	100.00
15	43.48	15	29.44	44.46	76.07	58.27	52.56
16	43.08	1	34.09	61.82	21.58	83.04	42.79
17	43.05	21	44.54	84.08	0.33	31.85	14.50
18	42.79	32	37.52	38.40	37.75	81.24	51.29
19	41.79	28	29.81	29.55	82.14	60.93	51.25
20	40.62	9	20.77	81.81	56.46	46.26	15.61
21	40.26	12	39.43	59.87	11.58	58.79	19.14
22	39.46	2	30.22	17.66	54.79	100.00	52.03
23	39.15	11	30.22	77.86	12.04	43.94	24.53
24	38.87	18	19.81	94.99	12.17	75.49	11.88
25	37.33	34	27.21	72.74	24.47	51.87	6.38
26	36.53	10	11.15	82.26	75.00	16.42	32.14
27	35.81	26	25.00	67.04	27.50	46.50	22.63
28	34.46	29	6.73	67.06	87.68	31.85	27.00
29	33.06	25	21.16	50.00	70.83	.68	17.80
30	32.74	35	30.77	34.93	15.26	58.12	45.38
31	31.64	36	35.83	28.26	9.14	46.40	41.18
32	30.85	30	13.36	50.00	54.58	37.90	43.75
33	27.43	33	32.98	8.14	11.97	46.37	57.50
34	21.89	19	3.30	95.85	5.46	0.00	5.13
35	21.84	20	0.00	100.00	11.18	1.61	0.00
36	21.48	3	15.69	37.91	20.13	13.71	33.28

to have a slightly higher $WVUC_2$ score than project 4 though its contributions with respect to the last two criteria of employment and accessibility to social services are lower than that for project 4. Project 16 ranks first because it has a high utility for the benefits criteria and quite respectable utility for all the other four criteria. This is in contrast to some of the lower ranked projects which might have a very high utility for one or two criteria but very low utility for the other criteria.

In general, the ranking of a particular project, when cardinal weights are specified, depends on both the relative weights on the individual criterion and the relative performance of the criteria between projects in the set of projects to be ranked.

4.4.3 The Articulation of Ordinal Weights

When the decision maker is not willing and/or incapable of articulating cardinal weights, we assume that he/she will be willing and able to articulate ordinal weights on the criteria of interest. The analyst will need to spend some time with the decision maker to elicit his preferences concerning the relative ranking of the criteria.

The ordinal ranking of the criteria is a relatively small amount of information when compared to the cardinal weights for each of the criteria. However, even with this limited information, two functional decision rules have been derived by utilizing the concepts of linear programming problems. These two decision rules are the maximin decision rule and the maximax decision rule. The properties and biases of these two rules have been discussed in Section 3.5.3 and care has to be exercised in implementing either of these rules.

The maximax decision rule has been stated to be of a "more aggressive" or "less conservative" nature. If a situation arises whereby a contribution to the most preferred criteria is exceptionally good relative to any of the following criteria which might be exceptionally poor, the maximax rule will not be able to take it into account.

Table 4-15 shows the ranking of the thirty six projects using $WVUC_3^{MAX}$ with:

$$\begin{bmatrix}\text{economic}\\ \text{benefits}\\ \text{criteria}\end{bmatrix} > \begin{bmatrix}\text{economic}\\ \text{costs}\\ \text{criteria}\end{bmatrix} > \begin{bmatrix}\text{distribution}\\ \text{criteria}\end{bmatrix} > \begin{bmatrix}\text{employment}\\ \text{criteria}\end{bmatrix} > \begin{bmatrix}\text{accessibility}\\ \text{to social}\\ \text{services}\\ \text{criteria}\end{bmatrix}$$

where > means "is preferred to".

The five top-ranked projects (4,5,17,16 and 6) show the "more aggressive" nature of the maximax rule. The contribution of the most preferred criterion, economic benefits, overshadows the contributions of the other criteria. An extreme example is project 4 which has the highest utility with regards to the economic benefits criteria but has the lowest utility with regards to the distribution criteria. However when the contributions to the least preferred criteria is greater than that of the more preferred criteria, the former measures will exert an influence on the value of $WVUC_3^{MAX}$ (for example project 14).

The maximin decision rule on the other hand has a "more conservative" nature. The occurrence of a relatively exceptionally poor criterion measure is taken into account by this decision rule. On the other hand this decision rule is unable to reflect the occurrence of a relatively except-

TABLE 4-15: RANKING OF THE PROJECTS USING $WVUC_3^{MAX}$

(RANKING OF CRITERIA: ECONOMIC BENEFITS > ECONOMIC COSTS > DISTRIBUTION > EMPLOYMENT > ACCESSIBILITY TO SOCIAL SERVICES)

RANK NUMBER	$WVUC_3^{MAX}$	PROJECT NUMBER	$u(x_1)$	$u(x_2)$	$u(x_3)$	$u(x_4)$	$u(x_5)$
1	100.00	4	100.00	31.26	0.00	45.23	20.21
2	90.43	5	90.43	72.67	0.99	24.48	10.21
3	79.93	17	79.93	2.76	29.00	33.07	27.01
4	77.14	16	77.14	48.64	54.38	52.41	40.36
5	73.88	6	73.88	58.90	1.25	28.90	14.99
6	68.48	14	36.17	31.67	95.80	90.49	88.25
7	66.72	22	30.39	69.78	100.00	45.97	27.03
8	64.55	13	41.35	38.40	82.14	89.39	71.45
9	64.31	21	44.54	84.08	0.33	31.85	14.50
10	63.84	23	63.84	0.00	52.50	68.12	45.21
11	60.31	31	60.31	47.73	40.38	56.25	45.00
12	57.42	8	34.62	80.23	40.13	73.81	27.04
13	57.40	18	19.81	94.99	12.17	75.49	11.88
14	56.14	10	11.15	82.26	75.00	16.42	32.14
15	54.04	11	30.22	77.86	12.04	43.94	24.53
16	53.93	27	53.93	38.55	50.00	67.18	38.75
17	53.82	29	6.73	67.06	87.68	31.85	27.00
18	53.16	7	41.35	55.67	27.63	88.02	31.26
19	53.01	9	20.77	81.81	56.46	46.26	15.61
20	53.16	15	29.44	44.46	76.07	58.27	52.56
21	52.14	24	48.30	13.61	41.00	57.81	100.00
22	50.94	2	30.22	17.66	54.79	100.00	52.03
23	50.74	28	29.81	29.55	82.14	60.93	51.25
24	50.13	1	34.09	61.82	21.58	83.04	42.79
25	50.00	20	0.00	100.00	11.18	1.61	0.00
26	49.98	34	27.21	72.74	24.47	51.87	6.38
27	49.65	12	39.43	59.87	11.58	58.79	19.14
28	49.57	19	3.30	95.85	5.46	0.00	5.13
29	49.24	32	37.52	38.40	37.75	81.24	51.29
30	47.33	25	21.16	50.00	70.83	9.68	17.80
31	46.02	26	25.00	67.04	27.50	46.50	22.63
32	39.92	30	13.36	50.00	54.58	37.90	43.75
33	36.89	35	30.77	34.93	15.26	58.12	45.38
34	35.83	36	35.83	28.26	9.14	46.40	41.18
35	32.98	33	32.98	8.14	11.97	46.37	57.50
36	26.80	3	15.69	37.91	20.13	13.71	33.28

ionally good criterion measure. Thus if the ability to account for a relatively exceptionally poor criterion measure is critical as illustrated by the analogy of "a chain is as strong as its weakest link", then the use of the maximin decision rule is justifiable.

Table 4-16 shows the ranking of the thirty six projects using $WVUC_3^{MIN}$ with:

[economic benefits criteria] > [economic costs criteria] > [distribution criteria] > [employment criteria] > [accessibility to social services criteria]

The "more conservative" nature of this decision rule can be illustrated by the last two projects. Project 19 and project 20 are ranked thirty fifth and thirty sixth respectively since they have dismal scores of respectively 3.30 and 0 for the most preferred criterion. The fact that project 20 has the highest score of 100 and project 19 has the second highest score of 95.85 for the second preferred criterion has been overshadowed by their disastrous performance with respect to the most preferred criterion.

TABLE 4-16: RANKING OF THE PROJECTS USING $WVUC_3^{MIN}$

(RANKING OF CRITERIA: ECONOMIC BENEFITS > ECONOMIC COSTS > DISTRIBUTION > EMPLOYMENT > ACCESSIBILITY TO SOCIAL SERVICES)

RANK NUMBER	$WVUC_3^{MIN}$	PROJECT NUMBER	$u(x_1)$	$u(x_2)$	$u(x_3)$	$u(x_4)$	$u(x_5)$
1	54.59	16	77.14	48.64	54.38	52.41	40.36
2	49.47	31	60.31	47.73	40.38	56.25	45.00
3	46.24	27	53.93	38.55	50.00	67.18	38.75
4	41.35	7	41.35	55.67	27.63	88.02	31.26
5	39.87	13	41.35	38.40	82.14	89.39	71.45
6	39.76	5	90.43	72.67	0.99	24.48	10.21
7	39.34	4	100.00	31.26	0.00	45.23	20.21
8	37.52	32	37.52	38.40	37.75	81.24	51.29
9	35.58	6	73.88	58.90	1.25	28.90	14.99
10	35.06	21	44.54	84.08	0.33	31.85	14.50
11	36.96	12	39.43	59.87	11.58	58.79	19.14
12	34.62	8	34.62	80.23	40.13	73.81	27.04
13	34.35	17	79.93	2.76	29.00	33.07	27.01
14	34.09	1	34.09	61.82	21.58	83.04	42.79
15	33.92	14	36.17	31.67	95.80	90.49	88.25
16	31.92	23	63.84	0.00	52.50	68.12	45.21
17	30.96	24	48.30	13.61	41.00	57.81	100.00
18	30.39	22	30.39	69.78	100.00	45.97	27.03
19	30.22	11	30.22	77.86	12.04	43.94	24.53
20	29.68	28	29.81	29.55	82.14	60.93	51.25
21	29.44	15	29.44	44.46	76.07	58.27	52.56
22	27.21	34	27.21	72.74	24.47	51.87	6.38
23	26.99	35	30.77	34.93	15.26	58.12	45.38
24	25.00	26	25.00	67.04	27.50	46.50	22.63
25	24.41	36	35.83	28.26	9.14	46.40	41.18
26	23.94	2	30.22	17.66	54.79	100.00	52.03
27	21.16	25	21.16	50.00	70.83	9.68	17.80
28	20.77	9	20.77	81.81	56.46	46.26	15.61
29	19.81	18	19.81	94.99	12.17	75.49	11.88
30	17.70	33	32.98	8.14	11.97	46.37	57.50
31	15.69	3	15.69	37.91	20.13	13.71	33.28
32	13.36	30	13.36	50.00	54.58	37.90	43.75
33	11.15	10	11.15	82.26	75.00	16.42	32.14
34	6.73	29	6.73	67.06	87.68	31.85	27.00
35	3.30	19	3.30	95.85	5.46	0.00	5.13
36	0.00	20	0.00	100.00	11.18	1.61	0.00

4.4.4 A Summary

It has been asserted that it is not possible to suggest definitely which decision rule is the "best and only one" in the ranking of the set of projects under consideration. The "appropriate" decision rule to implement is environment (political, planning, etc.) and case specific, and is constrained by the type of value judgment that the analyst can elicit from the appropriate decision maker. Thus the adequate understanding by the analyst and the proper education of the decision maker concerning the properties and implications of the different decision rules are essential to the analysis.

As a summary, Table 4-17 shows the different rankings of the thirty six projects as a result of following different decision rules:

$WVUC_1$: equal weights on the criteria.

$WVUC_2$: cardinal weights on the criteria
with $W_1 = 0.5$, $W_2 = 0.2$, $W_3 = 0.15$, $W_4 = 0.1$, and
$W_5 = 0.05$

$WVUC_3^{MAX}1$: maximax rule with ordinal ranking
with $X_1 > X_2 > X_3 > X_4 > X_5$

$WVUC_3^{MIN}1$: maximin rule with ordinal ranking
with $X_1 > X_2 > X_3 > X_4 > X_5$

$WVUC_3^{MAX}2$: maximax rule with ordinal ranking
with $X_3 > X_2 > X_1 > X_4 > X_5$

TABLE 4-17: A SUMMARY COMPARISON OF RANKING USING DIFFERENT DECISION RULES

	$WVUC_1$	$WVUC_2$	$WVUC_3^{MAX}1$	$WVUC_3^{MIN}1$	$WVUC_3^{MAX}2$	$WVUC_3^{MIN}2$	$WVUC_3^{MAX}3$	$WVUC_3^{MIN}3$
1	14	16	4	16	22	22	20	8
2	13	5	5	31	14	14	19	22
3	22	4	17	27	29	13	18	16
4	16	31	16	7	28	16	21	31
5	15	13	6	13	13	15	10	9
6	24	6	14	5	10	28	9	10
7	8	14	22	4	15	27	5	18
8	2	27	13	32	25	9	8	7
9	28	22	21	6	9	29	11	5
10	31	17	23	21	8	10	34	1
11	27	23	31	12	16	31	22	27
12	32	8	8	8	20	8	14	13
13	7	7	18	17	2	30	29	32
14	1	24	10	1	5	32	26	26
15	23	15	11	14	30	2	6	11
16	9	1	27	23	18	25	4	12
17	29	21	29	24	7	7	13	15
18	10	32	7	22	23	26	16	29
19	18	28	9	11	27	24	1	34
20	30	9	15	28	24	23	12	6
21	5	12	24	15	31	34	7	21
22	4	2	2	34	19	1	31	25
23	12	11	28	35	1	3	27	30
24	26	18	1	26	32	17	15	14
25	11	34	20	36	34	35	24	4
26	35	10	34	2	26	18	2	28
27	34	26	12	25	11	11	28	35
28	6	29	19	9	6	12	30	36
29	21	25	32	18	4	20	25	20
30	17	35	25	33	21	33	32	19
31	25	36	26	3	12	36	23	3
32	36	30	30	30	17	19	17	2
33	33	33	35	10	35	6	3	24
34	3	19	36	29	36	5	35	33
35	20	20	33	19	33	21	36	17
36	19	3	3	20	3	4	33	23

TABLE 4-18: UTILITY OF THE CRITERIA MEASURES, $u(x_1)$

PROJECT NUMBER	ECONOMIC BENEFITS	ECONOMIC COSTS	DISTRIBUTION	EMPLOYMENT	ACCESSIBILITY TO SOCIAL SERVICES
1	34.09	61.82	21.58	83.04	42.79
2	30.22	17.66	54.79	100.00	52.03
3	15.69	37.91	20.13	13.71	33.28
4	100.00	31.26	0.00	45.23	20.21
5	90.43	72.67	0.99	24.48	10.21
6	73.88	58.90	1.25	28.90	14.99
7	41.35	55.67	27.63	88.02	31.26
8	34.62	80.23	40.13	73.81	27.04
9	20.77	81.81	56.46	46.26	15.61
10	11.15	82.26	75.00	16.42	32.14
11	30.22	77.86	12.04	43.94	24.53
12	39.43	59.87	11.58	58.79	19.14
13	41.35	38.40	82.14	89.39	71.45
14	36.17	31.67	95.80	90.49	88.25
15	29.44	44.46	76.07	58.27	52.56
16	77.14	48.64	54.38	52.41	40.36
17	79.93	2.76	29.00	33.07	27.01
18	19.81	94.99	12.17	75.49	11.88
19	3.30	95.85	5.46	0.00	5.13
20	0.00	100.00	11.18	1.61	0.00
21	44.54	84.08	0.33	31.85	14.50
22	30.39	69.78	100.00	45.97	27.03
23	63.84	0.00	52.50	68.12	45.21
24	48.30	13.61	41.00	57.81	100.00
25	21.16	50.00	70.83	9.68	17.80
26	25.00	67.04	27.50	46.50	22.63
27	53.93	38.55	50.00	67.18	38.75
28	29.81	29.55	82.14	60.93	51.25
29	6.73	67.06	87.68	31.85	27.00
30	13.36	50.00	54.58	37.90	43.75
31	60.31	47.73	40.38	56.25	45.00
32	37.52	38.40	37.75	81.24	51.29
33	32.98	8.14	11.97	46.37	57.50
34	27.21	72.74	24.47	51.87	6.38
35	30.77	34.93	15.26	58.12	45.38
36	35.83	28.26	9.14	46.40	41.18

$WVUC_3^{MIN}2$: maximin rule with ordinal ranking

with $X_3 > X_2 > X_1 > X_4 > X_5$

$WVUC_3^{MAX}3$: maximax rule with ordinal ranking

with $X_2 > X_1 > X_3 > X_4 > X_5$

$WVUC_3^{MIN}3$: maximin rule with ordinal ranking

with $X_2 > X_1 > X_3 > X_4 > X_5$

where: X_1 is the economic benefits criterion;

X_2 is the economic costs criterion;

X_3 is the distribution criterion;

X_4 is the employment criterion and

X_5 is the accessibility to social service criterion.

An observer may conclude that $WVUC_2$ has the same "ordinal ranking" as $WVUC_3^{MAX}1$ and $WVUC_3^{MIN}1$, and asserts that the rankings should be similar. It has to be stressed that this intuitive reasoning is not true. There is within the specification of cardinal weights ($WVUC_2$), an almost infinite number of variations that will parallel the "ordinal ranking" of $WVUC_3^{MIN}1$ and $WVUC_3^{MAX}1$. For each set of these cardinal weights, so specified, a different set of ranking may be the result. Thus, there is no basis for the comparison of the ranking produced by $WVUC_2$ with those of $WVUC_3^{MAX}1$, and $WVUC_3^{MIN}1$. Further, the amount of information contained in the specification of these two groups of decision rules is different, namely, cardinal versus ordinal.

Three projects (3,4,22) have been chosen to illustrate the possible fluctuations in the ranking of a particular project as a consequence of different decision rules with their resulting different preferences and types of information.

The movement of project 4 is an interesting one. This results from its extreme attainment of the various criteria (see Table 4-18); highest utility score of 100 with respect to the economic benefits criterion, lowest utility score of 0 with respect to the distribution criterion, a utility score of 45.23 with respect to the employment criterion and low utility scores of 31.26 and 20.21 with respect to the economic costs and accessibility criteria respectively. Thus, when equal weights ($WVUC_1$) are specified it is ranked number 22. However, when cardinal weights ($WVUC_2$) are specified, with a relatively higher weight on economic benefits, project 4 moves up to rank number 3, due to its extremely good score in this criterion. It ranks number one with $WVUC_3^{MAX}1$ which has economic benefits as the most preferred criterion but drops down to rank number 7 with $WVUC_3^{MIN}1$, which is a "more conservative" decision rule. As can be expected when $WVUC_3^{MAX}2$ and $WVUC_3^{MIN}2$ are utilized project 4 plunges down to rank number 29 and 36 respectively as a consequence of its poor performance with respect to the distribution criterion. In the case of $WVUC_3^{MAX}3$ and $WVUC_3^{MIN}3$, the respective ranking is 16 and 25 since its performance with respect to economic costs, the most preferred criterion in this instance, is relatively poor.

Project 22 has the best attainment with respect to the distribution criterion (see Table 4-18). It has a good score of 69.78 on the economic costs criterion and a lower score of 45.97 with respect to the employment criterion. Its performance with respect to the economic benefits and the accessibility to social services criteria is relatively poor at scores of 30.39 and 27.03 respectively. Correspondingly it ranks first for both $WVUC_3^{MAX}2$ and $WVUC_3^{MIN}2$ which have the ordinal ranking of $X_3 > X_2 > X_1 > X_4 > X_5$. Its performance for $WVUC_1$, $WVUC_2$, $WVUC_3^{MAX}1$, $WVUC_3^{MIN}3$ and $WVUC_3^{MAX}3$ is quite good with the respective rankings of 3,9,7,2 and 11. However, for $WVUC_3^{MIN}1$ its ranking drops down to number 18 since its score on the most preferred criterion is relatively poor in this case.

For project 3, it can be observed that its performance with respect to all the criteria is relatively poor (see Table 4-18); 15.69 for economic benefits, 37.91 for economic costs, 20.13 for distribution, 13.71 for employment and 33.28 for accessibility to social services. Correspondingly it ranks last for three decision rules ($WVUC_2$, $WVUC_3^{MAX}1$ and $WVUC_3^{MAX}2$) and ranks below 30 for the rest, except for $WVUC_3^{MIN}2$ when it rises a little to rank number 23.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 A SUMMARY AND CONCLUSION

From the introductory discussion, it was pointed out that the plight of the poorest rural populace is a problem that needs immediate attention. The tasks that have to be performed are enormous due to the magnitude and multi-faceted nature of the problem. It is recognized that, although transportation is generally an insufficient ingredient for rural development, it is a necessary ingredient.

Following an extensive literature review on rural road and other project evaluation techniques applicable in developing countries, an implementable multi-criteria appraisal framework for rural roads is formulated that is capable of incorporating, in addition to the traditional economic objective, other important socio-economic objectives, such as distribution, employment generation and accessibility to social services, in the appraisal of rural road projects. This is to ensure inclusion of the contributions to the multiple objectives of the rural development effort. The formulation of the framework involves the identification of, first, the relevant criteria, second, the ways in which the measures of the criteria might be collected and last, the ways in which the measures of the criteria might be combined to form an explicit value structure as a basis for decision making. Following this, a case study is structured to illustrate the implementation of the framework.

As a general conclusion, it has been demonstrated that it is conceptually possible to structure a multi-criteria appraisal framework to account for the multiple objectives of the rural development effort in the appraisal of rural transport projects.

The set of criteria that has been chosen is:

(1) economic benefits;

(2) economic costs;

(3) distribution;

(4) employment; and

(5) accessibility to social services

The above is not meant to imply universal representation for the socio-economic objectives of the rural development effort. It is only a possible set of representative criteria. The findings of further research may suggest some other relevant criteria; however, the multi-criteria framework that is formulated is independent of possible changes in the relevant criteria or the addition of more relevant criteria.

Three hypotheses have been postulated regarding the way in which value judgments might be articulated by the appropriate decision maker in the formulation of the explicit value structure as a basis for decision making. It is imperative that decision makers are properly educated on the implications of the resulting appropriate decision rule(s) for each case. As demonstrated in the case study a project* may rank first or last in the set of projects under consideration, depending on the type of

*This is an extreme case, see Section 4.4.4.

preferences articulated and the application of different decision rules.

The framework is very useful for the accounting of socio-economic objectives for the rural development effort. Thus, it will be highly applicable in a developing country context and especially so in anticipation of the large amount of resources that would be allocated to the development of the rural areas presently and in the near future. The utilization of this multi-criteria appraisal framework will help to impart a more valid basis for the selection of these rural development projects. This is important to ensure that the limited resources available in developing countries are put to its best uses. This is true too for the appraisal of rural transport projects by international lending agencies like the World Bank, etc.

5.2 RECOMMENDATIONS

The framework has been formulated at a conceptual level; and although a case study has been carried out to illustrate its implementation, there remains a need for it to be tested under actual field conditions. Thus, this is the first recommendation for future research efforts. Some of the measures that have been advocated have yet to be collected by any appraisal effort. Thus this effort entails collaboration with a road authority planning a program of rural roads in a developing country, or collaboration with a lending agency like the World Bank which allocates funds for rural transport projects. From these efforts, it will be possible to test policy makers'and other potential users' acceptance of the ideas and methods proposed.

In addition, the multi-criteria appraisal framework proposed in this study is "a first step" effort and consequently in this area, some refinements may be needed. For example, the use of land ownership by the target income group as a proxy in tracing the distribution of the economic benefits of projects, entails some restrictive assumptions. A new measure might be structured that lifts some of the restrictive assumptions.

As defined in the scope of this study in Chapter 1, this research effort has attempted only the appraisal problem. There are two other problem areas; the design problem and the implementation problem that need further study. Thus the design problem has to be looked at as a multi-objective design problem; the package of investments that need to be defined, identified, and situated in a regional context will be an extremely interesting one. This applies also to the implementation problem but with different emphasis and operational characteristics.

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APPENDIX A

EXAMPLES OF TI PROGRAMMABLE 59 PROGRAM LISTINGS

For the ranking analysis, the calculations necessary amount to a sizeable number. The analysis can be made more readily feasible with the aid of a programmable calculator. For this particular study, a TI Programmable 59 with an attached printer was utilized for the computational task. The availability of tiny magnetic cards enables the storage of programs and data. This calculator and others of similar capability are currently available at a reasonable cost.

A listing of some samples of the programs is presented to illustrate its ease of application and usefulness.

Listing A-1 is the program used for the input of data.

Listing A-2 is the program which uses the data for the criteria measures for all the projects and outputs for each project the values of:

$$\sum_{j=1}^{i} \frac{u(x_j)}{i} \qquad \text{for } i = 1, 2. \ldots . 5$$

where the ranking of the criteria is $x_1 > x_2 > x_3 > x_4 > x_5$

From this basic program only slight modifications are needed to compute values of $WVUC_1$, $WVUC_2$ or $WVUC_3^{MAX}$ and $WVUC_3^{MIN}$ where the ranking of the criteria is changed. Listing A-3 is an illustration of the case where the criteria ranking is $x_3 > x_1 > x_2 > x_4 > x_5$ and listing A-4 is the program for computing values of $WVUC_2$ where $w_1 = 0.5$, $w_2 = 0.2$, $w_3 = 0.15$, $w_4 = 0.1$ and $w_5 = 0.05$.

Finally for ordering the projects according to their scores on any of the decision parameters, listing A-5 is the program to use.

LISTING A-1: PROGRAM FOR DATA INPUT

```
000  76 LBL
001  12  B
002  06  6
003  42 STO
004  01  01
005  76 LBL
006  85  +
007  91 R/S
008  72 ST*
009  01  01
010  69 OP
011  21  21
012  99 PRT
013  61 GTO
014  85  +
```

LISTING A-2: PROGRAM FOR COMPUTATION OF $\sum_{j=1}^{i} \frac{u(x_j)}{i}$ FOR CRITERIA RANKING OF

$x_1 > x_2 > x_3 > x_4 > x_5$

```
000  76  LBL
001  11   A
002  42  STO
003  00   00
004  06   6
005  42  STO
006  02   02
007  76  LBL
008  85   +
009  06   6
010  52  EE
011  06   6
012  32  X:T
013  73  RC*
014  02   02
015  77   GE
016  38  SIN
017  16  A'
018  76  LBL
019  30  TAN
020  42  STO
021  03   03
022  99  PRT
023  69  OP
024  22   22
025  02   2
026  93   .
027  06   6
028  52  EE
029  06   6
030  32  X:T
031  73  RC*
032  02   02
033  77   GE
034  53   (
035  32  X:T
036  01   1
037  93   .
038  05   5
039  52  EE
040  06   6
041  32  X:T
042  77   GE
043  54   )
044  17  B'
045  76  LBL
046  52  EE
047  44  SUM
048  03   03
049  43  RCL
050  03   03
051  55   ÷
052  02   2
053  95   =
054  99  PRT
055  69  OP
056  22   22
057  07   7
058  02   2
059  00   0
060  32  X:T
061  73  RC*
062  02   02
063  77   GE
064  50  I×I
065  32  X:T
066  06   6
067  00   0
068  00   0
069  32  X:T
070  77   GE
071  34  ΓX
072  32  X:T
073  04   4
074  00   0
075  00   0
076  32  X:T
077  77   GE
078  35  1/X
079  18  C'
080  76  LBL
081  43  RCL
082  44  SUM
083  03   03
084  43  RCL
085  03   03
086  55   ÷
087  03   3
088  95   =
089  99  PRT
090  69  OP
091  22   22
092  03   3
093  08   8
094  52  EE
095  04   4
096  32  X:T
097  73  RC*
098  02   02
099  77   GE
100  99  PRT
101  19  D'
102  76  LBL
103  95   =
104  44  SUM
105  03   03
106  43  RCL
107  03   03
108  55   ÷
109  04   4
110  95   =
111  99  PRT
112  69  OP
113  22   22
114  01   1
115  02   2
116  52  EE
117  03   3
118  32  X:T
119  73  RC*
120  02   02
121  77   GE
122  98  ADV
123  10  E'
124  76  LBL
125  65   ×
126  44  SUM
127  03   03
128  43  RCL
129  03   03
130  55   ÷
131  05   5
```

LISTING A-2 (CONTINUED)

132	95	=
133	99	PRT
134	69	OP
135	22	22
136	98	ADV
137	97	DSZ
138	00	00
139	85	+
140	91	R/S
141	76	LBL
142	16	A'
143	75	-
144	08	8
145	00	0
146	00	0
147	06	6
148	03	3
149	02	2
150	54	)
151	65	×
152	05	5
153	00	0
154	55	÷
155	05	5
156	01	1
157	09	9
158	09	9
159	03	3
160	06	6
161	08	8
162	95	=
163	92	RTN
164	76	LBL
165	38	SIN
166	75	-
167	06	6
168	52	EE
169	06	6
170	54	)
171	65	×
172	05	5
173	00	0
174	55	÷
175	03	3
176	00	0
177	00	0
178	08	8
179	52	EE
180	03	3
181	54	)
182	85	+
183	05	5
184	00	0
185	95	=
186	61	GTO
187	30	TAN
188	76	LBL
189	17	B'
190	75	-
191	06	6
192	02	2
193	00	0
194	06	6
195	03	3
196	02	2
197	54	)
198	65	×
199	05	5
200	00	0
201	94	+/-
202	55	÷
203	08	8
204	07	7
205	09	9
206	03	3
207	06	6
208	08	8
209	54	)
210	85	+
211	01	1
212	00	0
213	00	0
214	95	=
215	92	RTN
216	76	LBL
217	53	(
218	75	-
219	02	2
220	06	6
221	52	EE
222	05	5
223	54	)
224	65	×
225	02	2
226	05	5
227	94	+/-
228	55	÷
229	09	9
230	52	EE
231	05	5
232	54	)
233	85	+
234	02	2
235	05	5
236	95	=
237	61	GTO
238	52	EE
239	76	LBL
240	54	)
241	75	-
242	01	1
243	05	5
244	52	EE
245	05	5
246	54	)
247	65	×
248	02	2
249	05	5
250	94	+/-
251	55	÷
252	01	1
253	01	1
254	52	EE
255	05	5
256	54	)
257	85	+
258	05	5
259	00	0
260	95	=
261	61	GTO
262	52	EE
263	76	LBL

LISTING A-2 (CONTINUED)

264	18	C'
265	75	-
266	02	2
267	00	0
268	54	)
269	65	×
270	02	2
271	05	5
272	55	÷
273	03	3
274	08	8
275	00	0
276	95	=
277	92	RTN
278	76	LBL
279	50	I×I
280	75	-
281	07	7
282	02	2
283	00	0
284	54	)
285	65	×
286	05	5
287	55	÷
288	05	5
289	06	6
290	54	)
291	85	+
292	07	7
293	05	5
294	95	=
295	61	GTO
296	43	RCL
297	76	LBL
298	34	√X
299	65	×
300	05	5
301	55	÷
302	02	2
303	04	4
304	75	-
305	07	7
306	05	5
307	95	=
308	61	GTO
309	43	RCL
310	76	LBL
311	35	1/X
312	65	×
313	01	1
314	55	÷
315	08	8
316	75	-
317	02	2
318	05	5
319	95	=
320	61	GTO
321	43	RCL
322	76	LBL
323	19	D'
324	75	-
325	01	1
326	03	3
327	02	2
328	52	EE
329	03	3
330	54	)
331	65	×
332	05	5
333	00	0
334	55	÷
335	02	2
336	04	4
337	08	8
338	52	EE
339	03	3
340	95	=
341	92	RTN
342	76	LBL
343	99	PRT
344	75	-
345	03	3
346	08	8
347	52	EE
348	04	4
349	54	)
350	65	×
351	05	5
352	00	0
353	55	÷
354	03	3
355	02	2
356	00	0
357	01	1
358	00	0
359	05	5
360	54	)
361	85	+
362	05	5
363	00	0
364	95	=
365	61	GTO
366	95	=
367	76	LBL
368	10	E'
369	65	×
370	93	.
371	00	0
372	00	0
373	06	6
374	02	2
375	05	5
376	95	=
377	92	RTN
378	76	LBL
379	98	ADV
380	65	×
381	93	.
382	00	0
383	02	2
384	05	5
385	75	-
386	02	2
387	02	2
388	05	5
389	95	=
390	61	GTO
391	65	×

LISTING A-3: PROGRAM FOR COMPUTATION OF $\sum_{j=1}^{i} \frac{u(x_j)}{i}$ FOR CRITERIA RANKING OF $x_3 > x_1 > x_2 > x_4 > x_5$

```
000  76  LBL
001  11   A
002  42  STO
003  00   00
004  06   6
005  42  STO
006  02   02
007  76  LBL
008  85   +
009  06   6
010  52  EE
011  06   6
012  32  X:T
013  73  RC*
014  02   02
015  77   GE
016  38  SIN
017  16  A'
018  76  LBL
019  30  TAN
020  42  STO
021  03   03
022  69  OP
023  22   22
024  02   2
025  93   .
026  06   6
027  52  EE
028  06   6
029  32  X:T
030  73  RC*
031  02   02
032  77   GE
033  53   (
034  32  X:T
035  01   1
036  93   .
037  05   5
038  52  EE
039  06   6
040  32  X:T
041  77   GE
042  54   )
043  17  B'
044  76  LBL
045  52  EE
046  42  STO
047  04   04
048  69  OP
049  22   22
050  07   7
051  02   2
052  00   0
053  32  X:T
054  73  RC*
055  02   02
056  77   GE
057  50  I×I
058  32  X:T
059  06   6
060  00   0
061  00   0
062  32  X:T
063  77   GE
064  34  ΓX
065  32  X:T
066  04   4
067  00   0
068  00   0
069  32  X:T
070  77   GE
071  35  1/X
072  18  C'
073  76  LBL
074  43  RCL
075  99  PRT
076  44  SUM
077  03   03
078  43  RCL
079  03   03
080  55   ÷
081  02   2
082  95   =
083  99  PRT
084  43  RCL
085  04   04
086  44  SUM
087  03   03
088  43  RCL
089  03   03
090  55   ÷
091  03   3
092  95   =
093  99  PRT
094  69  OP
095  22   22
096  03   3
097  08   8
098  52  EE
099  04   4
100  32  X:T
101  73  RC*
102  02   02
103  77   GE
104  99  PRT
105  19  D'
106  76  LBL
107  95   =
108  44  SUM
109  03   03
110  43  RCL
111  03   03
112  55   ÷
113  04   4
114  95   =
115  99  PRT
116  69  OP
117  22   22
118  01   1
119  02   2
120  52  EE
121  03   3
122  32  X:T
123  73  RC*
124  02   02
125  77   GE
126  98  ADV
127  10  E'
128  76  LBL
129  65   ×
130  44  SUM
131  03   03
132  43  RCL
```

LISTING A-3: (CONTINUED)

133	03	03
134	55	÷
135	05	5
136	95	=
137	99	PRT
138	43	RCL
139	03	03
140	99	PRT
141	69	OP
142	22	22
143	98	ADV
144	97	DSZ
145	00	00
146	85	+
147	91	R/S
148	76	LBL
149	16	A'
150	75	-
151	08	8
152	00	0
153	00	0
154	06	6
155	03	3
156	02	2
157	54	)
158	65	×
159	05	5
160	00	0
161	55	÷
162	05	5
163	01	1
164	09	9
165	09	9
166	03	3
167	06	6
168	08	8
169	95	=
170	92	RTN
171	76	LBL
172	38	SIN
173	75	-
174	06	6
175	52	EE
176	06	6
177	54	)
178	65	×
179	05	5
180	00	0
181	55	÷
182	03	3
183	00	0
184	00	0
185	08	8
186	52	EE
187	03	3
188	54	)
189	85	+
190	05	5
191	00	0
192	95	=
193	61	GTO
194	30	TAN
195	76	LBL
196	17	B'
197	75	-
198	06	6
199	02	2
200	00	0
201	06	6
202	03	3
203	02	2
204	54	)
205	65	×
206	05	5
207	00	0
208	94	+/-
209	55	÷
210	08	8
211	07	7
212	09	9
213	03	3
214	06	6
215	08	8
216	54	)
217	85	+
218	01	1
219	00	0
220	00	0
221	95	=
222	92	RTN
223	76	LBL
224	53	(
225	75	-
226	02	2
227	06	6
228	52	EE
229	05	5
230	54	)
231	65	×
232	02	2
233	05	5
234	94	+/-
235	55	÷
236	09	9
237	52	EE
238	05	5
239	54	)
240	85	+
241	02	2
242	05	5
243	95	=
244	61	GTO
245	52	EE
246	76	LBL
247	54	)
248	75	-
249	01	1
250	05	5
251	52	EE
252	05	5
253	54	)
254	65	×
255	02	2
256	05	5
257	94	+/-
258	55	÷
259	01	1
260	01	1
261	52	EE
262	05	5
263	54	)
264	85	+

LISTING A-3: (CONTINUED)

265	05	5
266	00	0
267	95	=
268	61	GTO
269	52	EE
270	76	LBL
271	18	C'
272	75	-
273	02	2
274	00	0
275	54	)
276	65	×
277	02	2
278	05	5
279	55	÷
280	03	3
281	08	8
282	00	0
283	95	=
284	92	RTN
285	76	LBL
286	50	I×I
287	75	-
288	07	7
289	02	2
290	00	0
291	54	)
292	65	×
293	05	5
294	55	÷
295	05	5
296	06	6
297	54	)
298	85	+
299	07	7
300	05	5
301	95	=
302	61	GTO
303	43	RCL
304	76	LBL
305	34	√X
306	65	×
307	05	5
308	55	÷
309	02	2
310	04	4
311	75	-
312	07	7
313	05	5
314	95	=
315	61	GTO
316	43	RCL
317	76	LBL
318	35	1/X
319	65	×
320	01	1
321	55	÷
322	08	8
323	75	-
324	02	2
325	05	5
326	95	=
327	61	GTO
328	43	RCL
329	76	LBL
330	19	D'
331	75	-
332	01	1
333	03	3
334	02	2
335	52	EE
336	03	3
337	54	)
338	65	×
339	05	5
340	00	0
341	55	÷
342	02	2
343	04	4
344	08	8
345	52	EE
346	03	3
347	95	=
348	92	RTN
349	76	LBL
350	99	PRT
351	75	-
352	03	3
353	08	8
354	52	EE
355	04	4
356	54	)
357	65	×
358	05	5
359	00	0
360	55	÷
361	03	3
362	02	2
363	00	0
364	01	1
365	00	0
366	05	5
367	54	)
368	85	+
369	05	5
370	00	0
371	95	=
372	61	GTO
373	95	=
374	76	LBL
375	10	E'
376	65	×
377	93	.
378	00	0
379	00	0
380	06	6
381	02	2
382	05	5
383	95	=
384	92	RTN
385	76	LBL
386	98	ADV
387	65	×
388	93	.
389	00	0
390	02	2
391	05	5
392	75	-
393	02	2
394	02	2
395	05	5
396	95	=
397	61	GTO
398	65	×
399	00	0

LISTING A-4: PROGRAM FOR COMPUTATION OF $WVUC_2$ WITH W_1 = 0.5, W_2 = 0.2, W_3 = 0.15, W_4 = 0.1 and W_5 = 0.05

```
000  76 LBL
001  11  A
002  42 STO
003  00  00
004  06  6
005  42 STO
006  02  02
007  76 LBL
008  85  +
009  06  6
010  52 EE
011  06  6
012  32 X:T
013  73 RC*
014  02  02
015  77  GE
016  38 SIN
017  16 A'
018  76 LBL
019  30 TAN
020  65  ×
021  93  .
022  05  5
023  95  =
024  42 STO
025  03  03
026  69 OP
027  22  22
028  02  2
029  93  .
030  06  6
031  52 EE
032  06  6
033  32 X:T
034  73 RC*
035  02  02
036  77  GE
037  53  (
038  32 X:T
039  01  1
040  93  .
041  05  5
042  52 EE
043  06  6
044  32 X:T
045  77  GE
046  54  )
047  17 B'
048  76 LBL
049  52 EE
050  65  ×
051  93  .
052  02  2
053  95  =
054  44 SUM
055  03  03
056  69 OP
057  22  22
058  07  7
059  02  2
060  00  0
061  32 X:T
062  73 RC*
063  02  02
064  77  GE
065  50 IXI
066  32 X:T
067  06  6
068  00  0
069  00  0
070  32 X:T
071  77  GE
072  34 √X
073  32 X:T
074  04  4
075  00  0
076  00  0
077  32 X:T
078  77  GE
079  35 1/X
080  18 C'
081  76 LBL
082  43 RCL
083  65  ×
084  93  .
085  01  1
086  05  5
087  95  =
088  44 SUM
089  03  03
090  69 OP
091  22  22
092  03  3
093  08  8
094  52 EE
095  04  4
096  32 X:T
097  73 RC*
098  02  02
099  77  GE
100  99 PRT
101  19 D'
102  76 LBL
103  95  =
104  65  ×
105  93  .
106  01  1
107  95  =
108  44 SUM
109  03  03
110  69 OP
111  22  22
112  01  1
113  02  2
114  52 EE
115  03  3
116  32 X:T
117  73 RC*
118  02  02
119  77  GE
120  98 ADV
121  10 E'
122  76 LBL
123  65  ×
124  65  ×
125  93  .
126  00  0
127  05  5
128  95  =
129  44 SUM
130  03  03
131  43 RCL
```

LISTING A-4 (continued)

132	03	03
133	99	PRT
134	69	OP
135	22	22
136	98	ADV
137	97	DSZ
138	00	00
139	85	+
140	91	R/S
141	76	LBL
142	16	A'
143	75	-
144	08	8
145	00	0
146	00	0
147	06	6
148	03	3
149	02	2
150	54	)
151	65	×
152	05	5
153	00	0
154	55	÷
155	05	5
156	01	1
157	09	9
158	09	9
159	03	3
160	06	6
161	08	8
162	95	=
163	92	RTN
164	76	LBL
165	38	SIN
166	75	-
167	06	6
168	52	EE
169	06	6
170	54	)
171	65	×
172	05	5
173	00	0
174	55	÷
175	03	3
176	00	0
177	00	0
178	08	8
179	52	EE
180	03	3
181	54	)
182	85	+
183	05	5
184	00	0
185	95	=
186	61	GTO
187	30	TAN
188	76	LBL
189	17	B'
190	75	-
191	06	6
192	02	2
193	00	0
194	06	6
195	03	3
196	02	2
197	54	)
198	65	×
199	05	5
200	00	0
201	94	+/-
202	55	÷
203	08	8
204	07	7
205	09	9
206	03	3
207	06	6
208	08	8
209	54	)
210	85	+
211	01	1
212	00	0
213	00	0
214	95	=
215	92	RTN
216	76	LBL
217	53	(
218	75	-
219	02	2
220	06	6
221	52	EE
222	05	5
223	54	)
224	65	×
225	02	2
226	05	5
227	94	+/-
228	55	÷
229	09	9
230	52	EE
231	05	5
232	54	)
233	85	+
234	02	2
235	05	5
236	95	=
237	61	GTO
238	52	EE
239	76	LBL
240	54	)
241	75	-
242	01	1
243	05	5
244	52	EE
245	05	5
246	54	)
247	65	×
248	02	2
249	05	5
250	94	+/-
251	55	÷
252	01	1
253	01	1
254	52	EE
255	05	5
256	54	)
257	85	+
258	05	5
259	00	0
260	95	=
261	61	GTO
262	52	EE
263	76	LBL

LISTING A-4 (continued)

264	18	C'
265	75	-
266	02	2
267	00	0
268	54	)
269	65	×
270	02	2
271	05	5
272	55	÷
273	03	3
274	08	8
275	00	0
276	95	=
277	92	RTN
278	76	LBL
279	50	I×I
280	75	-
281	07	7
282	02	2
283	00	0
284	54	)
285	65	×
286	05	5
287	55	÷
288	05	5
289	06	6
290	54	)
291	85	+
292	07	7
293	05	5
294	95	=
295	61	GTD
296	43	RCL
297	76	LBL
298	34	ΓX
299	65	×
300	05	5
301	55	÷
302	02	2
303	04	4
304	75	-
305	07	7
306	05	5
307	95	=
308	61	GTD
309	43	RCL
310	76	LBL
311	35	1/X
312	65	×
313	01	1
314	55	÷
315	08	8
316	75	-
317	02	2
318	05	5
319	95	=
320	61	GTD
321	43	RCL
322	76	LBL
323	19	D'
324	75	-
325	01	1
326	03	3
327	02	2
328	52	EE
329	03	3
330	54	)
331	65	×
332	05	5
333	00	0
334	55	÷
335	02	2
336	04	4
337	08	8
338	52	EE
339	03	3
340	95	=
341	92	RTN
342	76	LBL
343	99	PRT
344	75	-
345	03	3
346	08	8
347	52	EE
348	04	4
349	54	)
350	65	×
351	05	5
352	00	0
353	55	÷
354	03	3
355	02	2
356	00	0
357	01	1
358	00	0
359	05	5
360	54	)
361	85	+
362	05	5
363	00	0
364	95	=
365	61	GTD
366	95	=
367	76	LBL
368	10	E'
369	65	×
370	93	.
371	00	0
372	00	0
373	06	6
374	02	2
375	05	5
376	95	=
377	92	RTN
378	76	LBL
379	98	ADV
380	65	×
381	93	.
382	00	0
383	02	2
384	05	5
385	75	-
386	02	2
387	02	2
388	05	5
389	95	=
390	61	GTD
391	65	×

LISTING A-5: PROGRAM FOR THE RANKING OF PROJECTS

```
000  76  LBL
001  11   A
002  42  STO
003  04   04
004  42  STO
005  01   01
006  76  LBL
007  53   (
008  43  RCL
009  04   04
010  42  STO
011  00   00
012  06   6
013  42  STO
014  02   02
015  73  RC*
016  02   02
017  76  LBL
018  44  SUM
019  32  X:T
020  43  RCL
021  02   02
022  42  STO
023  03   03
024  76  LBL
025  52  EE
026  69  OP
027  22   22
028  73  RC*
029  02   02
030  77   GE
031  44  SUM
032  97  DSZ
033  00   00
034  52  EE
035  43  RCL
036  03   03
037  75   -
038  05   5
039  95   =
040  99  PRT
041  73  RC*
042  03   03
043  99  PRT
044  98  ADV
045  94  +/-
046  72  ST*
047  03   03
048  06   6
049  97  DSZ
050  01   01
051  53   (
052  91  R/S
```

APPENDIX B: FORMULATION OF THE MAXIMUM AND MINIMUM WEIGHTED VALUES FOR THE ORDINAL RANKING OF CRITERIA

To begin, let's state the following:

a) The number of independent criteria under consideration total m.

b) The weights, W_i, (i=1, 2, ...m) corresponding to each criteria is not specified but the order of their preference is specified. They are ranked as follows:

$$W_1 \geqq W_2 \geqq \ldots\ldots\ldots \geqq W_m$$

c) The weights are normalized:

$$\sum_{i=1}^{m} W_i = 1.0$$

Now, for each project let's deal with the problem of determining the maximum and minimum weighted values of the criteria, $WVUC_3$. One way of formalizing this problem is to treat it as two linear programming problems.

The formulation is:

$$\text{Maximize (Minimize) } WVUC_3 = \sum_{i=1}^{m} W_i \, u(x_i) \qquad \text{(B-1)}$$

Subject to:

$$\sum_{i=1}^{m} W_i = 1 \qquad \text{(B-2)}$$

$$W_i - W_{i+1} \geqq 0 \qquad \text{(B-3)}$$

$(i = 1, \ldots\ldots m - 1)$ (this reflects the ordering of the criteria)

$$W_i \geqq 0 \qquad \text{(B-4)}$$

$(i = 1, \ldots\ldots\ldots m)$

Two transformations will be introduced to help simplify the problem. These are:

$$Z_i = W_i - W_{i+1} \qquad \text{(B-5)}$$

$(i = 1, 2, \ldots\ldots m-1)$

$$M_i = \sum_{j=1}^{i} u(x_j) \qquad \text{(B-6)}$$

$(i - 1, 2, \ldots. m)$

It is observed that since $W_{m+1} = 0$, $Z_m = W_m$

It can be shown that

$$\sum_{i=1}^{m} iZ_i = 1 \qquad \text{(B-7)}$$

is the transformation of (B-2) as follows:

$$\sum_{i=1}^{m} iZ_i + 2(Z_2) \ldots\ldots\ldots + m(Z_m) \qquad \text{(B-8)}$$

$$= 1(W_1 - W_2) + 2(W_2 - W_3) + e(W_3 - W_4) \ldots\ldots\ldots + (m - 1)(W_{m-1} - W_m) + mW_m$$

$$= W_1 + W_2 + W_3 + \ldots\ldots W_m$$

$$= \sum_{i=1}^{m} W_i$$

The non-negativity constraints (B-4) can be shown to hold:

$$W_1 > W_2 > W_3 \ldots\ldots\ldots > W_m \qquad \text{(B-9)}$$

$$Z_i \; (= W_i - W_{i+1}) \quad \geqq 0$$

If any W_i is negative W_{i+1} must be "more negative" for (B-9) to hold.

But $W_m = Z_m$ and (B-9) would not hold if any negative value enters into the sequence.

Therefore, $W_i \geqq 0$ $(i=1,.....m)$ will hold true by the specification of

$$Z_i \geqq 0 \qquad \text{(B-9)}$$

It can also be shown that $\sum_{i=1}^{m} Z_i M_i$ is the transformation of $\sum_{i=1}^{m} W_i\ u(x_i)$ as follows:

$$\sum_{i=1}^{m} Z_i M_i = (W_1 - W_2)u(x_1) + (W_2 - W_3)[u(x_1) + u_2)] + (W_3 - W_4)[u(x_1) + u(x_2)$$

$$+ u(x_3)] \ldots + (W_{m-1} - W_m)[u(x_1) + u(x_2) \ldots u\ (x_{m-1})]$$

$$+ W_m[u(x_1) + u(x_3) \ldots + u(x_m)\ ]$$

$$= W_1 u(x_1) - W_2 u(x_1) + W_2 u(x_1) + W_2 u(x_2) - W_3[u(x_1) + u(x_2)]$$

$$+ W_3[u(x_1) + u(x_2)] + W_3 u(x_3) - W_4[u(x_1) + u(x_2) + u(x_3)]$$

$$+ \ldots + W_{m-1}[u(x_1) + u(x_2) + \ldots + u(x_{m-2})]$$

$$+ W_{m-1}u(x_{m-1}) - W_m[u(x_1) + u(x_2) + \ldots = u(x_{m-1})]$$

$$+ W_m[u(x_1) + u(x_2) + \ldots + u(x_{m-1})] + W_m u(x_m)$$

$$= W_1 u(x_1) + W_2 u(x_2) + \ldots + W_m(x_m)$$

$$= \sum_{i=1}^{m} W_i\ u(x_i) \qquad \text{(B-10)}$$

Thus, finally the original formulation has transformed to the following:

$$\text{Maximize (Minimize) } WVUC_3 = \sum_{i=1}^{m} M_i Z_i \qquad \text{(B-11)}$$

subject to

$$\sum_{i=1}^{m} iZ_i = 1 \qquad \text{(B-12)}$$

$$Z_i \geqq 0 \qquad \text{(B-13)}$$