PROVISION OF RURAL TRANSPORT INFRASTRUCTURES

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1. INTRODUCTION

The World Bank is currently participating in financing rural road construction and improvement in many developing countries. This takes place in projects which fall in the transport sector and in the context of agricultural and rural development projects. Before deciding to participate, the World Bank carries out an appraisal of rural transport infrastructure proposed for improvement and/or construction. As a consequence of scarce resources, not all projects governments wish to undertake can be approved. There is therefore a strong need for simplified techniques.

Based on a recent review of 20 project appraisal reports and relevant literature, this paper suggests simple operational approaches to the screening and economic appraisal of components of rural road and rural development projects. The objective is to simplify screening and appraisal methods without reducing their reliability to unacceptable levels. The proposed screening methods are based on the principles of discriminant analysis or a process of finding a quick and rough estimation of an economic return (ER). Discriminant analysis is a simple statistical technique to classify project components or groups of interdependent components into two sets: likely feasible and unfeasible ones. Simplified economic appraisal procedures are presented in increasing order of complexity. If a proposed investment passes the test of a simple method, no further analysis is needed. If it does not pass this appraisal, the use of a more time-consuming method is recommended. In other words, the simplest method becomes the final appraisal if as a result of its application a proposed investment is accepted.

2. CONSUMER SURPLUS VS. PRODUCER SURPLUS

The consumer surplus (CS) approach to the economic evaluation of components of rural road projects stresses the quantification of road user savings. This method, which is sometimes referred to as the vehicle operating cost (VOC) savings method, is best suited for cases where the existing or normal traffic, or its projected growth, is substantial and the estimated transport cost savings are a reliable measure of project benefits. The producer surplus (PS) or value added approach to the economic analysis of project components stresses the assessment of economic activity, particularly agricultural production, in the rural road's zone of influence. The PS method is best suited for situations where there are reasonably accurate data regarding boundaries of the zone of influence, prices and yields of agricultural products produced in this area, and the agricultural potential. It has the advantage that it is intuitively more satisfying to non-economists; however, it cannot be applied to non-agricultural traffic. The PS approach establishes an investment package of agricultural and rural road investments in the zone of influence of a rural road or group of interdependent rural roads. These zones of influence are determined by (i) the rural road network around the road(s) being analyzed, (ii) the distance between farms and local markets, (iii) the terrain, and (iv) the means of transport used such as headloading, pack animals, animal-drawn carts, agricultural pickups, trucks, passenger cars, and buses.

In rural road projects without agricultural components, the costs of constructing, improving and maintaining rural roads are the principal costs to be considered in the economic evaluation. If such projects complement ongoing agricultural projects, the costs of existing agricultural investments are sunk costs and, therefore, should not be taken into account in the evaluation. The only PS value to be considered in this case is the value which could not be realized without the improved or new rural roads. Costs and benefits of components of planned (future) agricultural projects which are dependent on rural road components of a proposed rural road project should be considered together, regardless of potential source of financing. This situation calls for the formulation of investment packages consisting of interdependent rural road(s) and agricultural components.

The screening and simplified appraisal methods described below are based on the CS, or PS approach, or combinations thereof. They can be applied to individual rural roads, groups of interdependent rural roads and agricultural components. To identify the project elements, which through their appropriate design, standards and synergism, constitute an economically viable package of investment and production techniques, and to enhance project design, it is important to test interdependency among project components. That is, one first has to carefully specify the interrelationships between the various components. Next, an identification of all feasible and meaningful combinations of project components is called for. If, for instance, there are three components, A, B and C, the maximum number of options to choose from are A, B, C, A+B, B+C, A+C and A+B+C. Next, the net present value (NPV) or ER of each feasible combination is computed with one of the methods described below to determine whether it is economically viable. The identification of feasible project combinations of rural development projects or rural road projects complementing ongoing or planned agricultural projects calls for the consideration of possible interdependency among rural roads, among agricultural components, and among rural roads and agricultural components. For projects covering large areas, such consideration should start with a breakdown of subareas.

3. SCREENING

Application of screening methods based on economic criteria is desirable if one wishes to save time and costs of analyses by rejecting project components which are not likely to be economically viable, at an early stage of the analysis. Discriminant functions can be used to classify rural roads, interdependent groups of rural roads, or investment packages of rural road and agricultural investments into one of two groups, defined as feasible and unfeasible. For purposes of presentation, the criterion of feasibility is defined for a country with a prevailing opportunity cost of capital of 12%. To find out whether a project component is feasible or not, one computes S_1 and S_2 values with the help of the following equations:

$$S_1 = -98.54 + 113.60\ x + 256.82\ y + 0.32\ z$$

$$S_2 = -359.66 + 451.75\ x + 745.35\ y + 0.81\ z$$

where x = incremental agricultural value added in the year of full production divided by the present value of costs of investments and maintenance of rural road and agricultural components,

y = opening year benefits stemming from savings in vehicle operating costs accruing to normal traffic, divided by the present value of the costs of investments and maintenance of rural road and agricultural components, and

z = initial or preproject net value in US dollars' equivalent of agricultural production per hectare of cultivated area in the road's zone of influence.

For a country with an opportunity cost of capital of 12%, a project component or group of interdependent components is feasible if the S_1 value is smaller than the S_2 value; otherwise, it is unfeasible. The World Bank has developed S_1 and S_2 expressions similar to the ones mentioned above and which apply to countries with prevailing opportunity costs of capital equal to 10%, 14% or 16%. The reliability of the discriminant analysis approach, or the probability that a project component will be accepted or rejected for further analysis when the component should correctly be so accepted or rejected, was tested with a worldwide sample of 110 rural roads with and without complementary investments, and was found to be 87%.

Another screening method[1/] involves the approximation of the ER of a project component or group of interdependent components. The component "passes" the screening or is selected for further analysis if the approximated ER equals or exceeds the opportunity cost of capital. The approximate ER is read from one of two tables each of which represents variations of standardized cost and net benefit streams. In other words, standardized cost and net benefit streams are selected as an approximation to the cost and benefit streams of project component(s) to be screened. The first standardized cost and net benefit streams consist of rectangular functions of costs and benefits as presented in Figure 1. This figure portrays a situation where costs of investment of project component(s) are $80 million in each of the first two years of implementation and annual net benefits amount to $35 million during years 3 through 15.

Table 1 presents ERs for variations of the cost and net benefit streams of Figure 1, where the variations consist of combinations of uniform costs incurred over a period from one to five years, and uniform benefits incurred over periods of 5, 10 and 20 years.

1/ This method was developed by Walter Schaefer-Kehnert of the World Bank (EDI Training Materials, Course Note Series, CN30, October 1981).

Figure 1: Uniform Cost and Net Benefit Streams

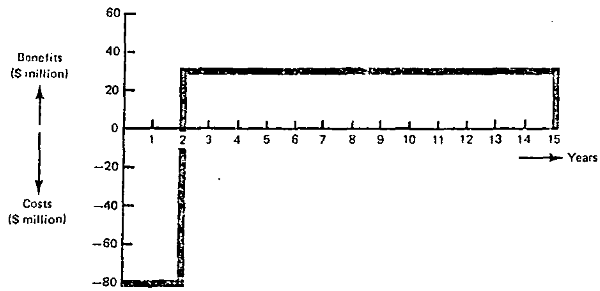


Table 1: ER of Uniform Cost and Net Benefit Streams

No. of Years with Investment Costs	No. of Benefit Years	Average Annual Net Benefits as % of Investment Costs							
		10	20	30	40	50	60	80	100
1	5	–	0	15	29	41	53	75	97
	10	0	15	27	38	49	59	80	100
	20	8	19	30	40	50	60	80	100
2	5	–	0	13	23	33	47	56	69
	10	0	13	24	32	40	48	61	73
	20	7	18	26	34	41	48	61	73
3	5	–	0	11	20	27	33	45	54
	10	0	12	21	28	34	40	50	58
	20	7	16	24	30	36	41	50	59
4	5	–	0	9	17	23	28	37	45
	10	0	11	19	25	30	35	42	49
	20	7	15	22	27	32	36	43	50
5	5	–	0	8	15	20	25	32	38
	10	0	10	17	22	27	31	37	42
	20	6	14	20	24	29	32	38	43

To explain the use of Table 1, consider the following simple example:

	Year 1	2	3	4	5–14
Investment Costs ($ million)	25	25	25	25	
Net Benefits ($ million)					50

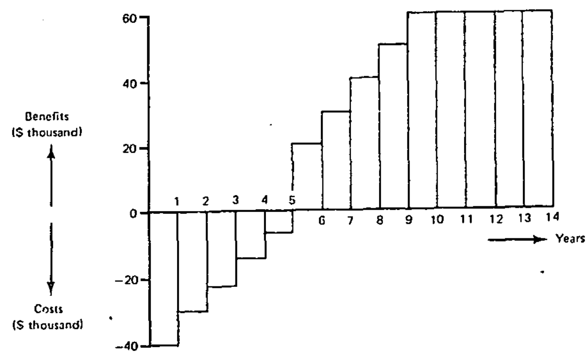
Thus, investment costs are incurred over a period of four years ($25 million per year) and annual net benefits amount to $50 million during years 5 through 14. One determines the sum of investment costs or $100 million; average net benefits or $50 million, and average annual net benefits as a percentage of investment costs or 50%. Table 1 indicates that these cost and benefit streams have an ER of 30%. If cost and benefit streams are indeed uniform functions, this ER is exact rather than an approximation.

If the cost and benefit streams to be analyzed are very uneven in the sense that investment costs are high at the beginning and then decline, and that annual net benefits gradually build up over a number of years before they stabilize, the ER can be considerably lower than shown in Table 1. The use of Table 2 is recommended to approximate these conditions. Table 2 is based on standardized cost and net benefit streams which assume a linear decline of the costs during a period ranging from one to five years followed by a linear buildup of annual net benefits of the first five years that follow. Figure 2 portrays an example of such standardized cost and net benefit streams.

Table 2: <u>ER of Standardized Uneven Cost and Net Benefit Streams</u>

No. of Years with Invest. Costs	No. of Benefit Years	Average Annual Net Benefits as % of Investment Costs							
		10	20	30	40	50	60	80	100
1	5	-	0	12	22	30	38	52	64
	10	0	12	21	28	34	40	50	59
	20	7	16	23	28	34	38	47	55
2	5	-	0	10	19	25	30	40	49
	10	0	11	18	24	29	34	42	48
	20	6	14	20	25	29	33	40	46
3	5	-	0	9	15	21	25	33	40
	10	0	10	16	21	26	29	36	41
	20	6	13	18	23	26	29	35	40
4	5	-	0	7	13	18	22	28	34
	10	0	9	15	19	23	26	31	36
	20	6	12	17	21	24	26	31	35
5	5	-	0	7	12	16	19	25	29
	10	0	8	13	17	21	23	28	32
	20	5	12	16	19	22	24	28	31

Figure 2: Standardized Uneven Cost and Net Benefit Streams



To illustrate the use of Table 2 as a tool to establish an approximate ER for screening purposes, consider the following example:

	Year								
	1	2	3	4	5	6	7	8-10	11-15
Investment Costs ($ 000)	11,200	2,806	402						
Net Benefits ($ 000)				3,189	6,795	7,997	4,497	7,997	12,000

Thus, the sum of investment costs equals $14,408 thousand, average annual net benefits amount to $8,872 thousand and represent 62% of $14,408 thousand. According to Table 2, the ER should be about 29%.

The reliability of the screening method which uses Table 1 or Table 2 depends on how close the underlying standardized cost and net benefit streams are to the cost and benefit streams to be analyzed. It is amazing how close the results often are, even with cost and benefit streams which do not appear to be very close to the standardized ones. For example, the actual ER pertaining to the aforementioned example is also equal to 29%. The use of Tables 1 and 2 is not recommended when annual net benefits decrease over time, since the approximated ER would in most cases be too much undervalued and, therefore, too many project components which deserve further analysis would be rejected. Fortunately, projects do not often have project components with decreasing annual net benefits.

4. SIMPLE ECONOMIC APPRAISAL METHODS

This section presents simple appraisal methods in increasing order of complexity. If a proposed rural road, group of interdependent rural roads or investment packages of interdependent rural road and agricultural components passes the test of a simple appraisal method, no further analysis is required unless the analyst wishes to know the percentage points by which an ER exceeds the opportunity cost of capital. In other words, to save time, one accepts a project component or group of interdependent components if its "simple" ER exceeds the opportunity cost of capital. "Simple" ER is defined as an ER based on a significant portion of quantifiable benefits rather than on all. Simple ERs are all understatements of actual ERs. If project component(s) do not pass a simple appraisal, the use of a more time-consuming method is recommended. The reliability of individual simple methods is of little interest if this approach is followed. The reliability of the approach is as good as the reliability of the most complex method proposed. This method, which is also based on a number of simplifications, was found to have a reliability of about 95%.

Method I is a simplified version of the CS approach. Its use is recommended in deciding whether an existing rural road should be improved, wherever (i) existing traffic is significant, (ii) potential producer surplus benefits are insignificant, (iii) traffic is expected to grow at a constant rate, and (iv) traffic composition is not going to change significantly. Traffic composition is the composition of types of vehicles such as private cars, motorcycles, horse- or ox-drawn vehicles, buses and cycles.

Method I uses Table 3 which is a tool for determining if a particular road improvement satisfies the condition that the ER equals the opportunity cost of capital (i) of 12% or more. It is assumed in this table that the average daily traffic (ADT) grows at a rate (g) of 5% per annum in the with-project situation and that the expected life of the rural road (N) is 10 years. The condition about the ER is then satisfied for any rural road having VOC and VOC savings (VOCs) as shown in the extreme left-hand columns, per kilometer costs of investments (CI) as shown in the top row of the table, and actual ADTs no less than what is shown at the intersection of the appropriate VOCs row and the appropriate CI column. The improvement costs are defined as the present value of construction and incremental maintenance costs. The following example illustrates the use of Table 3. Suppose a decision is to be made about the economic viability of a proposed rural road with the following characteristics: CI = \$25,000; VOC = \$0.50; VOCs = 25%; g = 5%; i = 12%; N = 10 years; and ADT = 95 (actual).

The above ADT of 95 is compared with the ADT of Table 3 which pertains to g = 5%, VOC = \$0.50, and VOCs = 25%. The proposed rural road is economically

Table 3: Critical Values of Average Daily Traffic 1/

N=10, g=5, i=12

VOC ($/KM)	VOCS % 2/	CI ($/KM) 8000	10000	18000	20000	25000	35000	50000	75000	125000	200000	250000
0.10	0.05	615	768	1383	1536	1920	2689	3841	5761	9602	15363	19204
0.10	0.10	307	384	691	768	960	1344	1920	2881	4801	7682	9602
0.10	0.15	205	256	461	512	640	896	1280	1920	3201	5121	6401
0.10	0.25	123	154	277	307	384	538	768	1152	1920	3073	3841
0.10	0.35	88	110	196	219	274	384	549	823	1372	2195	2743
0.10	0.50	61	77	138	154	192	269	384	576	960	1536	1920
0.10	0.75	41	51	92	102	128	179	256	384	640	1024	1280
0.25	0.05	246	307	553	615	768	1075	1536	2305	3841	6145	7682
0.25	0.10	123	154	277	307	384	538	768	1152	1920	3073	3841
0.25	0.15	82	102	184	205	256	358	512	768	1280	2048	2561
0.25	0.25	49	61	111	123	154	215	307	461	768	1229	1536
0.25	0.35	35	44	79	88	110	154	219	329	549	878	1097
0.25	0.50	25	31	55	61	77	108	154	230	384	615	768
0.25	0.75	16	20	37	41	51	72	102	154	256	410	512
0.50	0.05	123	154	277	307	384	538	768	1152	1920	3073	3841
0.50	0.10	61	77	138	154	192	269	384	576	960	1536	1920
0.50	0.15	41	51	92	102	128	179	256	384	640	1024	1280
0.50	0.25	25	31	55	61	77	108	154	230	384	615	768
0.50	0.35	18	22	40	44	55	77	110	165	274	439	549
0.50	0.50	12	15	28	31	38	54	77	115	192	307	384
0.50	0.75	8	10	18	20	26	36	51	77	128	205	256
1.00	0.05	61	77	138	154	192	269	384	576	960	1536	1920
1.00	0.10	31	38	69	77	96	134	192	288	480	768	960
1.00	0.15	20	26	46	51	64	90	128	192	320	512	640
1.00	0.25	12	15	28	31	38	54	77	115	192	307	384
1.00	0.35	9	11	20	22	27	38	55	82	137	219	274
1.00	0.50	6	8	14	15	19	27	38	58	96	154	192
1.00	0.75	4	5	9	10	13	18	26	38	64	102	128
2.00	0.05	31	38	69	77	96	134	192	288	480	768	960
2.00	0.10	15	19	35	38	48	67	96	144	240	384	480
2.00	0.15	10	13	23	26	32	45	64	96	160	256	320
2.00	0.25	6	8	14	15	19	27	38	58	96	154	192
2.00	0.35	4	5	10	11	14	19	27	41	69	110	137
2.00	0.50	3	4	7	8	10	13	19	29	48	77	96
2.00	0.75	2	3	5	5	6	9	13	19	32	51	64
4.00	0.05	15	19	35	38	48	67	96	144	240	384	480
4.00	0.10	8	10	17	19	24	34	48	72	120	192	240
4.00	0.15	5	6	12	13	16	22	32	48	80	128	160
4.00	0.25	3	4	7	8	10	13	19	29	48	77	96
4.00	0.35	2	3	5	5	7	10	14	21	34	55	69
4.00	0.50	2	2	3	4	5	7	10	14	24	38	48
4.00	0.75	1	1	2	3	3	4	6	10	16	26	32

1/ It is clear that the situations with some of the high ADTs and high costs of construction reported in this table are the exception for rural road and rural development projects; these situations have been included since they were observed in a few cases of the 20 projects reviewed.

2/ 0.05, 0.10, etc., mean a 5 percent, 10 percent, etc., saving in VOC of first column.

viable if the actual ADT (95 in the example) is equal to or greater than the ADT obtained from Table 3 (77 in the example); otherwise it is not. Thus, the rural road of the example is feasible. Interpolation between CI, VOC and VOCs values of Table 3 may be required if the actual figures are not found in the table.

The ADT figures represent passenger cars, vans, medium and large trucks, buses, motorcycles and animal-drawn vehicles. The VOC figures to be used are weighted averages of VOC of vehicles observed on the existing rural road. Tables similar to Table 3 for combinations of variations in i ranging from 10% to 18%, variations in g ranging from 5% to 15%, and values of N equal to 10 and 15 have been developed by the World Bank.

Method II uses tables similar to Table 4 which shows ERs for benefit streams growing at a compound rate of 5% and for periods of 10, 15, 20, 25, 30 and 40 years. Similar tables have been developed for growth rates between 6 and 20%. Use of the tables is recommended if (i) existing traffic is significant, (ii) potential producer surplus benefits are insignificant, and (iii) net benefits stemming from the improved rural road are expected to grow at a given compound rate.

To illustrate the use of Table 4, consider a road authority that is examining the gravelling of a rural road at a cost of $110,000. It estimates that this will save about $10,000 initially in VOC and these savings will increase each year at 5% per annum over an assumed 15-year life of the road. Thus, the ratio of investment costs over initial VOC savings is 11. Table 4 shows for such a ratio equal to 11.2679, an ER of 9% in the left column.

Table 5 presents the assumptions made in the development of Methods III-VII, which are based on the PS approach or a combination of the PS and CS approach. The larger the number of assumptions made for a method, the less time-consuming its application is.

Method III uses Table 6, which shows a crop's present unit value (CPV) as a function of years to achieve full potential benefits, project components' expected lives (N), and simple ERs. The table is used by first determining the value of agricultural production when full production is reached in the with-project situation, the corresponding value in the without-project situation, and the difference between these values. Calling this difference the approximate value added (AVA) one next establishes the ratio C/(AVA) where C is the present value of investment and maintenance costs of project components. The ER may now be obtained from Table 6 by locating the value closest to this ratio in the appropriate "years to achieve full potential agricultural benefits" column; the ER which corresponds to this value is read off in the first column of Table 6. The appropriate "years to achieve full potential agricultural benefits" column corresponds to the column with the number of years equal to the latest year of full production of a crop in the with-project situation. The World Bank has developed tables similar to Table 6 for values of N = 5, 15, 20 and 25.

The following example is presented to elucidate the use of Table 6. The construction of a 30 km gravel road and small irrigation works is proposed in a zone of influence of 6,500 ha. The opportunity cost of capital is 12%. Present values of costs of construction and maintenance of the road and irrigation works amount to $1.20 and $0.20 million, respectively; each of these components has an expected life of 10 years. Table 7 gives the crop area breakdown and the crops' yields for the without- and with-project situations. Local market prices of the products considered, wheat and tomatoes, are $150 and $60 per ton, respectively. Costs of wheat production per hectare are $80 for unimproved production and $90 for improved agricultural production technology. Similarly, the costs of production of tomatoes per hectare are $520 with unimproved and $550 with improved production technology.

Table 4: ER for Net Benefits Growing at 5% Compound Rate

ER \ N =	10 yrs	15 yrs	20 yrs	25 yrs	30 yrs	40 yrs
1	12.4587	20.7554	30.8305	43.0650	57.9219	97.8713
2	11.7691	19.0636	27.4958	37.2431	48.5107	76.5920
3	11.1327	17.5552	24.6260	32.4105	40.9806	60.8032
4	10.5444	16.2073	22.1477	28.3793	34.9162	48.9670
5	10.0000	15.0000	20.0000	25.0000	30.0000	40.0000
6	9.4955	13.9163	18.1324	22.1533	25.9881	33.1335
7	9.0275	12.9413	16.5027	19.7435	22.6925	27.8180
8	8.5927	12.0622	15.0759	17.6936	19.9674	23.6580
9	8.1884	11.2679	13.8225	15.9414	17.6991	20.3664
10	7.8118	10.5487	12.7177	14.4365	15.7986	17.7335
11	7.4608	9.8962	11.7408	13.1379	14.1961	15.6046
12	7.1331	9.3028	10.8741	12.0121	12.8361	13.8651
13	6.8269	8.7622	10.1028	11.0315	11.6748	12.4291
14	6.5405	8.2687	9.4143	10.1737	10.6770	11.2318
15	6.2723	7.8174	8.7978	9.4199	9.8146	10.2240
16	6.0209	7.4037	8.2440	8.7546	9.0649	9.3680
17	5.7849	7.0239	7.7452	8.1651	8.4095	8.6346
18	5.5632	6.6746	7.2946	7.6405	7.8334	8.0011
19	5.3547	6.3526	6.8864	7.1718	7.3245	7.4498
20	5.1585	6.0555	6.5155	6.7515	6.8726	6.9665
21	4.9736	5.7806	6.1778	6.3732	6.4693	6.5399
22	4.7991	5.5261	5.8693	6.0314	6.1080	6.1612
23	4.6345	5.2899	5.5870	5.7216	5.7827	5.8229
24	4.4789	5.0703	5.3278	5.4399	5.4887	5.5192
25	4.3318	4.8660	5.0894	5.1828	5.2219	5.2451
26	4.1925	4.6755	4.8696	4.9476	4.9789	4.9966
27	4.0605	4.4976	4.6664	4.7317	4.7569	4.7704
28	3.9353	4.3313	4.4783	4.5329	4.5532	4.5636
29	3.8166	4.1755	4.3037	4.3495	4.3659	4.3738
30	3.7037	4.0294	4.1414	4.1798	4.1931	4.1992

The computation of the ER proceeds as follows: Columns (20) and (21) of Table 7 present the sum of net agricultural production values for the two crops. The sixth year corresponds to the year where with-project production values are at maximum or full production, and the net value added for that year is $0.52 million. The ratio of the present value of costs to value added benefits in year 6 is given by $\frac{1.40}{0.52} = 2.69$. Searching in Table 6 under the column corresponding to year 6, the nearest value to the ratio is 2.8 which corresponds to an ER = 18%. This simple ER is an understatement. Method III clearly does not call for the computation of <u>all</u> values of columns (7) through (10), and (16) through (21) of Table 7. The values are only presented because they pertain to examples of other simplified methods described below.

Methods IV through VII consist of determining benefit streams and costs of investment and maintenance of rural roads and agricultural investments. With this information, one can easily determine the ER. Since techniques for calculating ERs are well known, they are not illustrated here. Method IV

Table 5: Underlying Assumptions of Methods III-VII

(1)	(2)	(3)	(4)	(5)	(6)
	Simple Method 1/				
Assumption	III	IV	V	VI	VII
Full production in the without-project situation is reached before or at the same time full production in the with-project situation is reached	X				
Negligible salvage values of investments of the investment package	X	X	X	X	X
No distinction between production patterns on farms of different size in road's zone of influence	X	X	X	X	X
No distinction between farmgate prices of on-farm consumption and prices of exports from the road's zone of influence	X	X	X	X	X
No consideration of on-farm consumption by animals	X	X	X	X	X
Local market prices in the with- and without-project situations remain the same	X	X	X	X	X
VOC savings related to non-agricultural traffic insignificant	X	X	X		
On-farm consumption in the with- and without-project situations negligible	X	X			
Value of production of the crops in the zone of influence in the with-project situation increases at linear rate until it levels off ("full production") while the corresponding value in the without-project situation either remains constant during the project's expected life or also increases at a linear rate until it levels off.	X				

1/ A check in one of the columns 2-6 means that the assumption of column (1) is made.

Table 6: Crop's Present Unit Value as a Function of Years to Achieve Full Potential Benefits (CPV) for N = 10

YEARS TO ACHIEVE FULL POTENTIAL AGRICULTURAL BENEFITS

	1	2	3	4	5	6	7	8	9	10	15	20
10%	6.1	5.7	5.3	4.9	4.5	4.1	3.8	3.5	3.2	2.9	1.9	1.5
11%	5.9	5.4	5.0	4.6	4.3	3.9	3.6	3.3	3.0	2.7	1.8	1.4
12%	5.7	5.2	4.8	4.4	4.0	3.7	3.4	3.1	2.8	2.6	1.7	1.3
13%	5.4	5.8	4.6	4.2	3.8	3.5	3.2	3.0	2.7	2.5	1.6	1.2
14%	5.2	4.8	4.4	4.0	3.7	3.4	3.1	2.8	2.5	2.3	1.5	1.2
15%	5.0	4.6	4.2	3.8	3.5	3.2	2.9	2.7	2.4	2.2	1.5	1.1
16%	4.8	4.4	4.0	3.7	3.3	3.0	2.8	2.5	2.3	2.1	1.4	1.0
17%	4.7	4.2	3.8	3.5	3.2	2.9	2.6	2.4	2.2	2.0	1.3	1.0
18%	4.5	4.1	3.7	3.3	3.0	2.8	2.5	2.3	2.1	1.9	1.3	0.9

Table 7: Crop Area Breakdown, Yields and Production Values

	WHEAT									TOMATOES						
Year	w/o Proj. Areas (000ha)	w/Project Areas (000 ha) Unimp	Imp	Yields (ton/ha) Unimp	Imp	Production (000tons) w/o	With	Production Value (000$) w/o	With	w/o Project Areas (000ha)	w/Project Areas (000 ha) Unimp	Imp	Yields (ton/ha) Unimp	Imp	Production (000tons) w/o	With
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1	4.00	4.00	1.00	0.56	0.90	2.240	3.140	16	61	0.30	0.30	0.16	9.11	15.0	2.733	5.133
2	4.50	3.50	2.00	0.59	0.90	2.655	3.865	38	120	0.30	0.20	0.18	9.55	20.0	2.865	5.980
3	4.50	3.10	2.40	0.61	1.00	2.750	4.291	53	180	0.30	0.20	0.28	10.00	20.0	3.000	7.600
4	4.85	2.00	3.50	0.63	1.00	3.055	4.760	70	239	0.40	0.10	0.39	10.00	20.0	4.000	8.800
5	4.90	1.00	4.70	0.65	1.00	3.190	5.350	87	300	0.50	0.00	0.50	10.00	20.0	5.000	10.000
6	5.00	0.00	6.00	0.70	1.00	3.500	6.000	125	360	0.50	0.00	0.50	10.00	20.0	5.000	10.000
7	5.00	0.00	6.00	0.70	1.00	3.500	6.000	125	360	0.50	0.00	0.50	10.00	20.0	5.000	10.000
8	5.00	0.00	6.00	0.70	1.00	3.500	6.000	125	360	0.50	0.00	0.50	10.00	20.0	5.000	10.000
9	5.00	0.00	6.00	0.70	1.00	3.500	6.000	125	360	0.50	0.00	0.50	10.00	20.0	5.000	10.000
10	5.00	0.00	6.00	0.70	1.00	3.500	6.000	125	360	0.50	0.00	0.50	10.00	20.0	5.000	10.000

Year	Production Value (000$) w/o	With	Prod Value (all crops) (000$) w/o	With	Value Added (all crops) (000$)
(1)	(18)	(19)	(20)	(21)	(22)
1	8	64	24	125	101
2	16	130	54	248	194
3	24	198	77	378	301
4	32	261	102	500	398
5	40	325	127	625	498
6	40	325	165	685	520
7	40	325	165	685	520
8	40	325	165	685	520
9	40	325	165	685	520
10	40	325	165	685	520

Note: Column 7 = Column (2) x Column (5)
" 8 = Column (3) x Column (5) + Column (4) x Column (6)
" 9 = Column (7) x $150 - Column (2) x $80
" 10 = Column (8) x $150 - Column (3) x $80 - Column (4) x $90
" 16 = Column (11) x Column (14)
" 17 = Column (12) x Column (14) + Column (13) x Column (15)
" 18 = Column (16) x 60 - Column (11) x $520
" 19 = Column (17) x 60 - Column (12) x $520 - Column (13) x $550
" 20 = Column (9) + Column (18)
" 21 = Column (10) + Column (19)
" 22 = Column (21) - Column (20)

consists of carrying out Steps 1 through 6 of the following step-by step procedure; Method V calls for carrying out Steps 1 through 7, while Method VI calls for carrying out Steps 1 through 8. The procedure is:

Step 1: determine for each crop in the zone of influence in the without-project situation the annual production during the expected life by computing the product of "area cultivated with this crop" times "its yield";

Step 2: determine for each crop in the zone of influence in the with-project situation the annual production during the expected life by computing the sum of "unimproved area cultivated with the crop" times "its yield" and "improved area cultivated with the crop" times "its yield";

Step 3: with the prevailing local market price and annual production of Steps 1 and 2, calculate annual production values in the without- and with-project situations and consequent annual incremental production values;

Step 4: for each crop in the zone of influence, detemine annual incremental agricultural production costs during the expected life;

Step 5: for each crop in the zone of influence, determine the annual incremental transport costs during the expected life;

Step 6: estimate annual incremental road maintenance costs (routine and periodic);

Step 7: for each crop in the zone of influence, determine the difference between the products of "annual home consumption" times "economic costs of transport" in the without- and with-project situations; and

Step 8: determine VOC savings related to non-agricultural traffic (the manner in which this is done is not discussed here, since this is done elsewhere in the literature, as in "The Economic Benefits of Road Transport Projects", by H. G. van der Tak and A. Ray, World Bank Staff Occasional Paper No. 13, 1971).

Results of Steps 3 through 6 together with costs of investments of rural roads and agricultural components are all the data necessary to establish the simple ER with Method IV. Results of Steps 3 through 7 together with these investment costs suffice to determine the simple ER with Method V, while Method VI calls for the results of Steps 3 through 8. Further simplifications in carrying out the steps may be introduced by doing the calculations only for every 2 or 3 years of the expected life and obtaining values for intervening years by interpolation. Another further simplification may be introduced in carrying out the step-by-step procedure by applying it first to the major crops in the zone of influence. If an acceptable simple ER is obtained, computations related to other minor crops can be omitted; otherwise, they have to be carried out to check the resulting ER. While following

Table 8: Annual Agricultural Production, Transport and Road Maintenance Costs

Year	Agricultural Production Costs ('000$) Without-Situation		Agricultural Production Costs ('000$) With-Situation		Incremental Agricultural Production Costs ('000$)		Transport Costs $ per ton km		Agricultural Transport Costs ('000$) Without-Situation		Agricultural Transport Costs ('000$) With-Situation	
	Wheat	Tomatoes	Wheat	Tomatoes	Wheat	Tomatoes	Without	With	Wheat	Tomatoes	Wheat	Tomatoes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1	328.00	156.60	423.00	245.40	95.00	88.80	8.70	3.30	19.49	23.77	10.36	16.94
2	369.00	156.60	477.00	230.40	108.00	73.80	8.70	3.30	23.10	24.93	12.75	19.73
3	369.00	156.60	482.20	259.80	113.20	103.20	8.70	3.30	23.93	26.10	14.16	25.08
4	397.70	208.80	496.50	268.65	98.80	59.85	8.70	3.30	26.58	34.80	15.71	29.04
5	401.80	261.00	528.50	277.50	126.70	16.50	8.70	3.30	27.75	43.50	17.66	33.00
6	410.00	261.00	570.00	277.50	160.00	16.50	8.70	3.30	30.45	43.50	19.80	33.00
7	410.00	261.00	570.00	277.50	160.00	16.50	8.70	3.30	30.45	43.50	19.80	33.00
8	410.00	261.00	570.00	277.50	160.00	16.50	8.70	3.30	30.45	43.50	19.80	33.00
9	410.00	261.00	570.00	277.50	160.00	16.50	8.70	3.30	30.45	43.50	19.80	33.00
10	410.00	261.00	570.00	277.50	160.00	16.50	8.70	3.30	30.45	43.50	19.80	33.00

Incremental Agricultural Transpt. Costs ('000$)		Road Maintenance Costs ('000$)		Incremental Road Maintenance Costs ('000$)
Wheat	Tomatoes	Without	With	
(14)	(15)	(16)	(17)	(18)
-9.13	-6.83	0	0	0
-10.35	-5.20	0	0	0
- 9.77	-1.02	0	10	10
-10.87	-5.76	0	10	10
-10.09	-10.50	0	10	10
- 9.78	-10.50	0	25	25
-10.65	-10.50	0	10	10
-10.65	-10.50	0	10	10
-10.65	-10.50	0	10	10
-10.65	-10.50	0	25	25

The agricultural production costs include both the agricultural production costs of Table 7 and the annual costs of the extension services. The annual costs of extension services per hectare are $2 for unimproved production and $5 for improved production technology.

<u>Note</u>: Column (6) - Column (4) - Column (2)
Column (7) - Column (5) - Column (3)
Column (10) - Column (7) of Table 7 times Column (8)
Column (11) - Column (16) of Table 7 times Column (8)
Column (12) - Column (8) of Table 7 times Column (9)
Column (13) - Column (17) of Table 7 times Column (9)
Column (14) - Column (12) - Column (10)
Column (15) - Column (13) - Column (11)
Column (18) - Column (17) - Column (16)

this further simplification, one should, however, take into account costs of agricultural investments for both major and minor crops.

The following example illustrates the use of the step-by-step procedure with Method IV. The construction of a 30 km gravel road and wells together with a strengthening of extension services are proposed in a zone of influence of 6,500 ha. Costs of constructing the road and wells amount to $1.00 and $0.20 million, respectively. The expected life of these components is 10 years. Table 7 gives the crop area breakdown and the crops' yield, while Table 8 shows the crops' annual production costs, including costs of extension services, costs per ton of transport, and road maintenance costs in the with- and without-project situations. The costs per ton of transport in columns (8) and (9) have been arrived at by multiplying the length of the road (30 km) by the per ton-km transport costs in the without- and with-project situations ($0.29 and $0.11, respectively). Results of:

Step 1 are shown in columns (7) and (14) of Table 7,
Step 2 are shown in columns (8) and (15) of Table 7,
Step 3 are shown in columns (20), (21) and (22) of Table 7,
Step 4 are shown in columns (6) and (7) of Table 8,
Step 5 are shown in columns (14) and (15) of Table 8,
Step 6 are shown in column (18) of Table 8.

The investment costs of $1.00 and $0.20 million and cost and benefit streams obtained from carrying out Steps 3 through 6 result in an ER of 30.99%.

To determine home consumption as required in Step 7, the population in the zone of influence is first determined. Referring to the above example, suppose the area of influence has a base population of 60,000 which is growing at a rate of 2.5% per annum and has a per capita home consumption of 15 kg and 12 kg of wheat and 0.5 kg and 0.3 kg of tomatoes in the without- and with-project situation, respectively. Table 9 shows the results of Step 7 applied to this example. The H_1, k_1, H_2 and k_2 of the products H_1k_1 and H_2k_2 of Table 9 are defined as follows:

H_1, H_2 = on-farm (home) consumption of an agricultural crop produced in the area of influence, in the without- and with-project situation, respectively (tons), and

k_1, k_2 = economic costs of transport over the rural road in the without- and with-project situation, respectively ($ per ton).

Method VII consists of Steps 1 through 8 of the aforementioned step-by-step procedure with the following alteration and addition:

- replace "the prevailing local market price" of Step 3 by "the farmgate price in the without-project situation" ($/ton), and

- add the following step to Steps 1 through 8 --

Step 9: for each crop in the zone of influence, determine the product of "freight rate for transporting one ton of agricultural products on the rural road in the without-project situation" times "annual incremental exports from the zone of influence."

Table 9: Annual On-Farm Consumption, H_1k_1, and H_2,k_2

Year	Population ('000)	Wheat On Farm Consumption ('000 tons)		Tomatoes On Farm Consumption ('000 tons)		Wheat 1/			Tomatoes 1/		
		Without (H_1)	With (H_2)	Without (H_1)	With (H_2)	$H_1 k_1$ (000 $)	$H_2 k_2$ ('000$)	(H_1k_1 H_2k_2) ('000$)	H_1k_1 ('000 $)	$H_2 k_2$ ('000 $)	($H_1 k_1 - H_2 k_2$) ('000 $)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	60.00	0.90	0.90	0.03	0.03	7.83	2.97	4.86	0.26	0.10	0.16
2	61.50	0.92	0.92	0.03	0.03	8.00	3.04	4.96	0.26	0.10	0.16
3	63.00	0.95	0.76	0.03	0.02	8.26	2.51	5.75	0.26	0.07	0.19
4	66.20	0.99	0.79	0.03	0.02	8.61	2.61	6.00	0.26	0.07	0.19
5	67.80	1.02	0.81	0.03	0.02	8.87	2.67	6.20	0.26	0.07	0.19
6	69.50	1.04	0.83	0.03	0.02	9.05	2.74	6.31	0.26	0.07	0.19
7	71.30	1.07	0.86	0.04	0.02	9.31	2.84	6.47	0.35	0.07	0.28
8	73.10	1.10	0.88	0.04	0.02	9.57	2.90	6.67	0.35	0.07	0.28
9	74.90	1.12	0.90	0.04	0.02	9.74	2.97	6.77	0.35	0.07	0.28
10	76.80	1.15	0.92	0.04	0.02	10:01	3.04	6.97	0.35	0.07	0.28

1/ k_1 and k_2 values are given in Columns (8) and (9) of Table 8, respectively.

Note: Column 7 = Column (3) times Column (8) of Table 8
Column 8 = Column (4) times Column (9) of Table 8
Column 10= Column (5) times Column (8) of Table 8
Column 11= Column (6) times Column (9) of Table 8
Column (9) = Column (7) - Column (8)
Column (12) = Column (10) - Column (11)

The underlying assumptions of Methods VI and VII are the same. The difference between the two methods is that Method VI uses local market prices while Method VII uses farmgate prices.

To save time, it is important to know which simplified method to start with and in what sequence to try other methods. For instance, it would not make sense to start with Methods I or II if existing traffic is insignificant and significant producer surplus benefits are anticipated. Alternatively, it would not be wise to start with Method III if significant VOC savings related to non-agricultural traffic are expected. If one foresees significant CS and PS benefits, the first simple method to be used should be Method VI. In situations where only significant PS benefits are expected, and on-farm consumption is insignificant, the sequence of Methods III, IV, and VII without VOC savings related to non-agricultural traffic may be right.

5. CONCLUSION

This paper addresses the problem many governments are faced with, i.e., how to reduce time and costs of the preparation of rural road and rural development projects. Two alternate screening procedures and seven alternate simple economic appraisal methods, which can also be used to test the economic viability of different rural infrastructure plans and design standards, are proposed. Based on testing the methods with a worldwide sample of 110 individual rural roads with and without complementary agricultural investments, their reliability was found to be high.