APPENDIX C
DESIGNING BASIC ACCESS RTI FOR NON-MOTORIZED MEANS OF TRANSPORT

Introduction

For local short-distance movements and non-motorized transport users, simple improvements to paths and tracks can be of significant benefit to local communities by making them safer and easier to use. In addition, strategic investments can often reduce seasonal or sporadic periods of poor passability. In general, improvements of water crossings are the most cost-effective and easy–to–identify problem spots, although, in some cases, surface improvements (such as gravelling and stone pitching) of high-traffic sections might also be merited. The most common problems on paths and trails that reduce functionality are:

- slipperiness and erosion (caused by poor drainage or steep gradients),
- wet, marshy, or seasonally flooded areas of poor passability,
- dangerously steep and/or rocky sections, and
- difficult and/or seasonal stream or river crossings.

Identifying Problems on Paths and Tracks

Identifying access constraints on paths and tracks begins with consultation with users and a visual field survey to identify local conditions (soils, drainage, and grade). Local users identify the most heavily traveled and problematic routes in and around villages and to major destination points, as well as what type of transport takes place over those routes. They make distinctions between regular and seasonal problems. A rapid field survey is required to get a picture of local conditions and help in selecting preliminary strategies for overcoming current problems. If necessary, a further technical survey may be undertaken after initial consultations to obtain more precise observations and measurements of the paths and tracks identified. An outline of a technical survey is given in Box C.1.

Box C.1. ***Technical Survey of Path or Track***

Technical surveys are carried out to gather information on the physical condition of a path or track. Information is usually only recorded for the section where there are existing or potential problems. The type of observations and measurements required are:

- reference number and location of section (relative to obvious landmarks),
- length of section (can be paced, but preferably measured with a tape),
- soil type,
- gradient of path or trail,
- crossfall (sideways slope) of surrounding land,
- type of problem (slippery section, erosion), and
- details of the situation with possible solutions (sketches and notes).

The survey is usually carried out by an engineer or technician, but it is preferable if the technician is accompanied by the users of the path or track, who can point out or confirm the problem areas.

Source: Gary Taylor, 1994.

Design of Improvements

As is the case with motorized access, the design of path and track improvements requires knowledge concerning local conditions (terrain, soils, and environment), local institutional capacity and arrangements, transport patterns and other problems. After initial technical information concerning problems (and possible solutions) has been collected, the next step is to obtain information concerning the level and types of traffic. For high-volume paths and tracks, this may require traffic counts, while for very low-volume situations, estimates based on population served may yield sufficient accuracy. For engineering requirements, the primary concern of the transport survey is to assess design options based on users (types and sizes of loads and vehicles) and the level of daily traffic along the path or tracks. The information that should be collected includes daily and hourly counts of the numbers and types of means of transport and porters and their loading characteristics. If there is a need to prioritize among alternative investments, these counts can be supplemented with on-site user surveys to collect the information for priority evaluation. The survey process described in Appendix D can be adapted to paths and tracks.

Typical Improvements

Once traffic and loading characteristics have been determined, standard design parameters are used to determine the appropriate level of investment. Most often, the least-cost method for improving paths and trails to all-weather passability is community-driven spot improvements. In some cases, where transport demand is high and benefits adequate, full upgrading of the path or track along its entire length may be justified. Technical assistance is needed for designing the spot improvements and managing the works.

Essential first-stage design parameters for basic access paths or trails are camber and crossfall, width, and gradient:

- ***Camber and Crossfall*****—**Camber and crossfall are essential for proper surface drainage and should be a minimum of 5 percent in rainy areas, and higher in areas of heavy seasonal rain. A camber as low as 3 percent is possible in arid areas, but flat paths and tracks are not recommended.

- ***Width***—Width is determined by the requirements for passing and the loading characteristics (dimensions) of the NMT using the path. For basic access footpaths, one-way pedestrian traffic requires a width of approximately one meter. For tracks, animal or cart-loading characteristics will determine the required width and should be considered. A typical single-lane track will have a width of 1.4 meters.

- ***Maximum Gradient*****—**Paths are common in hilly or mountainous areas where road construction is difficult or too costly. The maximum gradient depends on the composition of the traffic. Pedestrians can ascend very steep slopes, although steps are necessary above 26 percent. However, wheeled vehicles and heavily loaded porters require much shallower gradients. The desirable maximum longitudinal gradients together with a summary of basic access standards for non-motorized access are summarized in Table C.1.

Table C.1. *Basic Standards for Non-Motorized Access*			
Feature	Terrain		
	Flat	**Rolling**	**Steep**
Path width	1 to 2 m, depending on traffic density and type	1 to 2 m, depending on traffic density and type	1 m
Path surface	In-situ soils except on sand or steep erodible slopes		
Camber	5%	5%	5%
Maximum gradient	N/A	7% for bicycles 8% for animal drawn carts 12% for pedestrians and pack animals 26 to 70% for pedestrians when steps provided	
Drainage structures and water crossings	Stepping stones, timber footbridges, suspension bridges		
Special features	Earth or brushwood causeways in marshy areas	Timber water bars	Hairpin bends, steps, handrails, timber water bars
Source: Authors.			

Surfacing

Most paths and tracks have developed naturally from the passage of traffic. The compaction of the soil by pedestrians, animals, and light vehicles is usually sufficient to give a satisfactory surface. The addition or replacement of surfacing material is relatively expensive and can only be justified in special circumstances such as the occurrence of marshy areas, very rough terrain, very sandy soils, or easily erodible soils on steep slopes.

Where the major problem is an erodible surface, a single layer of well compacted gravelly soil may be adequate. A certain amount of clay mixed in with the gravel helps bind the material to produce a dense impermeable surface layer. Stone pitching or "Telford" construction may be necessary for heavy traffic or on steep gradients. Figure C.1 illustrates some of these methods.

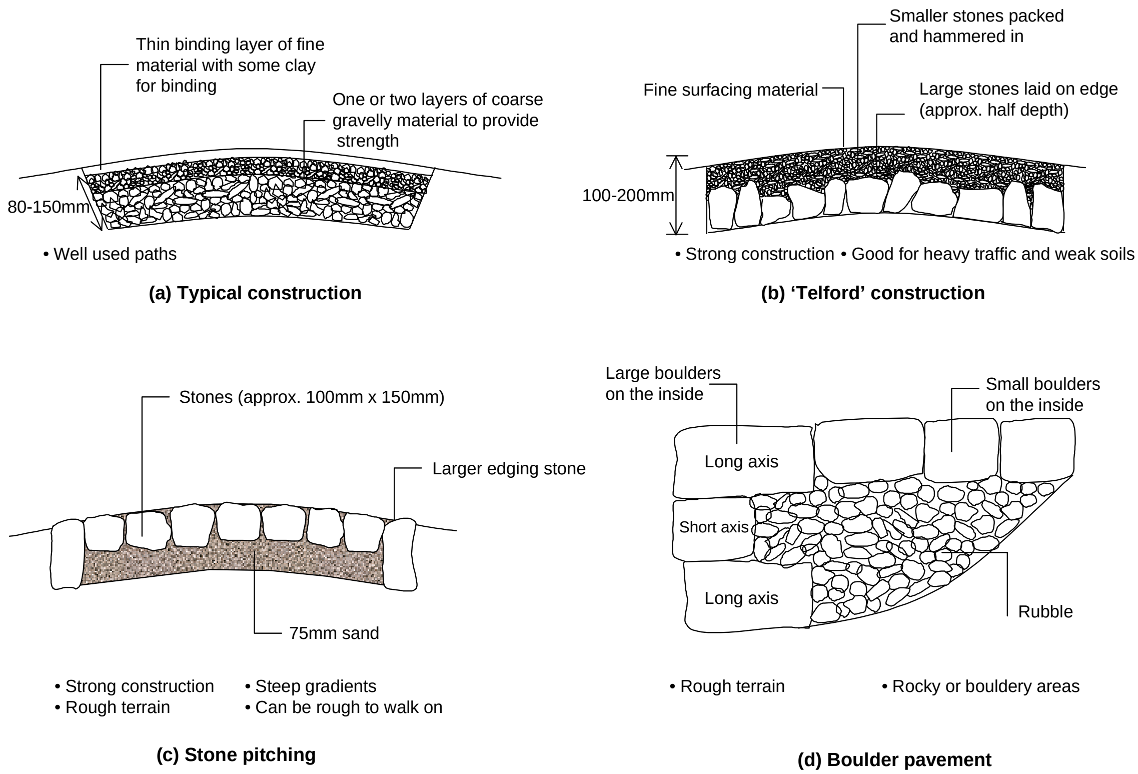
In wet or marshy areas, it is necessary to use different techniques to minimize the costs. There are three main approaches:[102]

- Stepping stones or stone causeways, in which large stones are firmly set in the ground to provide a stable walkway. This is only suitable for pedestrian traffic.

- Rafts or boardwalks, in which a timber walkway is built to sit on top of the wet soil. These are usually of light construction, for pedestrian or cycle traffic only.

- Turnpike sections, where the path or track is raised as a small embankment, with the edge constrained by logs or rocks. Brushwood or geo-textile membranes may be used to prevent the embankment from sinking. This is a relatively expensive solution suitable for short stretches of 50 meters or less. This approach is also useful for areas of loose sand.

Figure C.1. ***Surfacing Methods***



Source: Gary Taylor.

Erosion Control

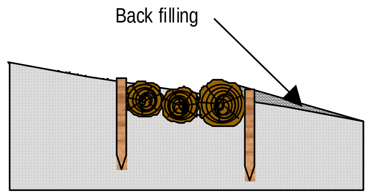
Surface water running down paths and tracks must be diverted before it erodes or saturates the surface. Similarly, surface water in ditches must also be diverted from those ditches before the bottoms begin to erode. Areas of natural water cross-flow must be managed in order to properly maintain surface and formation integrity. The primary low-cost methods of diverting water from non-motorized road surfaces are water-bars and drifts.

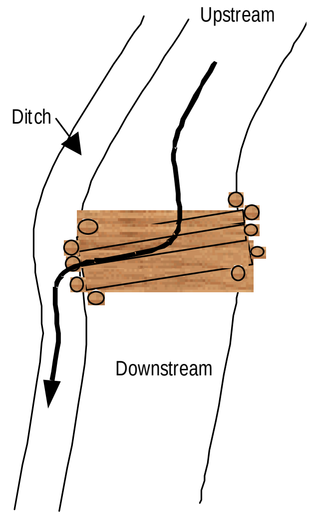
Design guidelines for the use of water-bars are given in Figure C.2.

For very steep gradients where only foot traffic is anticipated, it may be appropriate to build steps. However, these must be properly dimensioned to allow people carrying heavy loads to keep up a constant rhythm when ascending or descending. Tread lengths should be between one-half and one meter (equivalent to one or two paces) and the rise should be in the order of 160 to 250 mm. In any flight of steps, the rise should be consistent throughout.

Figure C.2. ***Water-Bar Guidelines***

Gradient of path	*Angle of water-bar*
5 %	25^0
10%	35^0
12%	45^0





Recommended spacing of water-bars (meters)

	Longitudinal Gradient in %					
Type of soil	*2*	*4*	*6*	*8*	*10*	*12*
Loam	100	50	30	20	15	*
Clay-sand	150	100	60	50	30	15
Clay or clay-gravel	-	150	90	60	50	30
Gravel/rocky	-	-	230	150	100	80

* Gradient not recommended in this type of soil

\- Water-bar not usually required

Source: Authors.

Timber, Culverts, and Footbridges

It is not usually necessary or cost-effective to use concrete culverts or other substantial structures for non-motorized access. However, timber culverts and footbridges can be used for continuous or deep stream and river crossings.

These structures do not have the strength of normal highway structures, and it is important that access is restricted to avoid overloading. Ensuring that the structures are less than two-meters wide is the most reliable approach.

Examples of a timber culvert, and design parameters for a timber footbridge are given in Table C.2 and Figure C.3 below. For long spans over deep water or gorges, the best approach is the construction of a suspension bridge. This is a specialized structure that should be designed by an experienced engineer. A number of publications are available covering this area.[103]

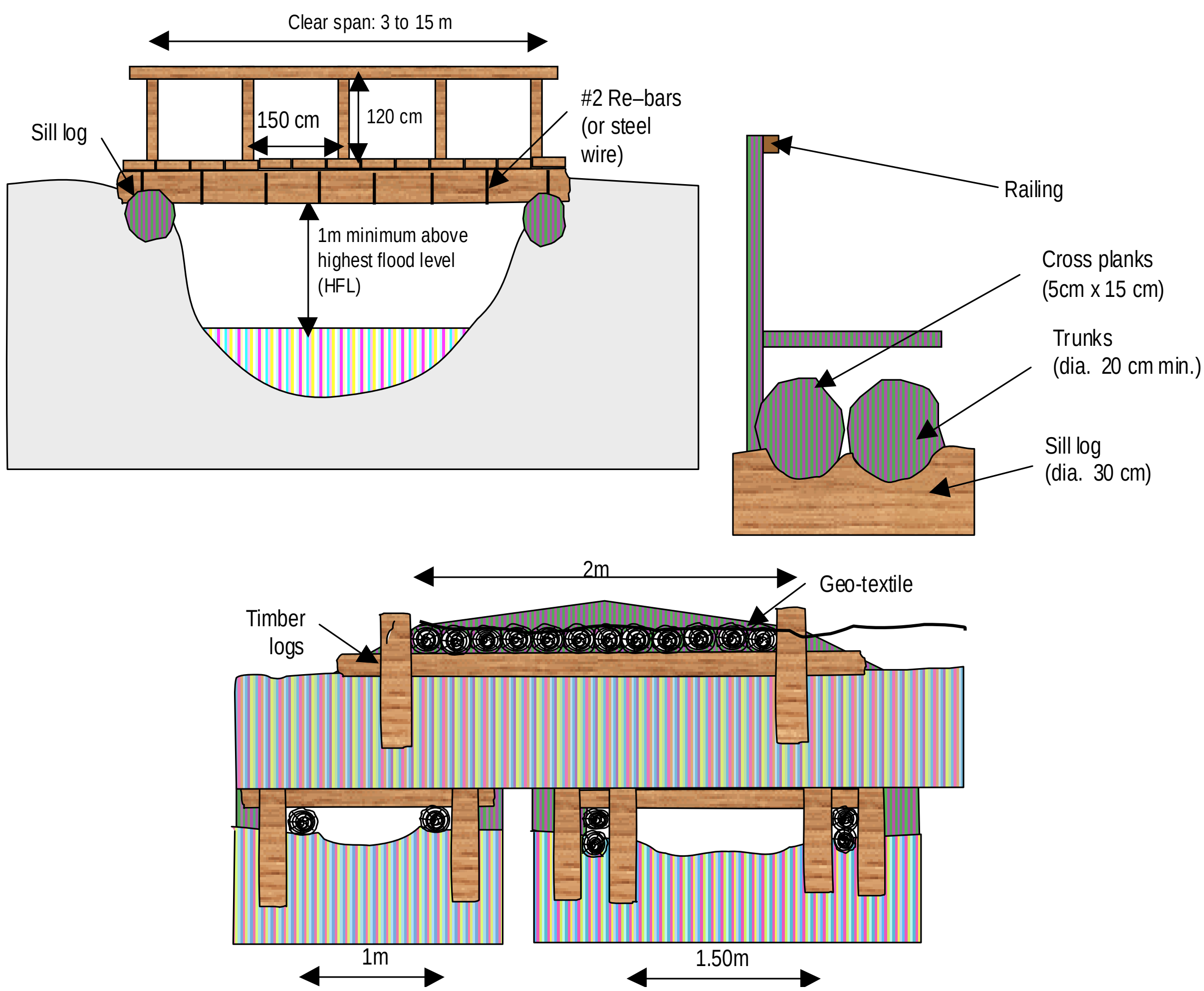
The following table relates the maximum clear span to the diameter of the logs required.

Table C.2. ***Timber Footbridge***

Maximum clear span (meters)	3	6	9	12	15
Log diameter (centimeters)	20	25	30	40	50

Source: Authors.

Figure C.3. ***Timber Culvert***



Source: Authors.

APPENDIX D
LOW-COST TRAFFIC SURVEY METHODS FOR RTI

Rural transport planners often face a lack of traffic data concerning RTI, and scarce resources for collecting new data. In addition, there may be weak institutional capacity for data collection and management at the local government or community level, which can be further compounded by poorly defined networks, ownership, and responsibilities.

Information on traffic, however, is essential for effective design and appraisal of RTI, particularly when upgrading to a higher than least-cost basic access standard or for investments motivated by economic objectives. If proposed improvements are to be appraised on a cost-effectiveness basis, traffic data samples should be collected and correlated with other indicators, such as populations served by the particular RTI. For socioeconomic impact studies, household-level mobility studies are required, including data on means of transport, trip purpose, origin and destination of trip and duration, in addition to other socioeconomic data.

The following two types of low-cost traffic surveys are described here:

- Moving Observer Count (MOC)
- Manual Traffic Survey (MTS)

The MOC is a rapid method of assessment suitable for categorizing roads into broad flow bands. The MTS is a more discerning and complete survey method, but requires considerable capacity and resources for appropriate execution.

Traffic Survey Form and Calculation of Average Daily Traffic (ADT)

A sample of a typical survey form is attached to this appendix. It can be used for both MOC and MTS surveys. Different categories of motorized and non-motorized vehicles are listed. These can be adjusted to reflect the actual existing types of vehicles in use in a particular area. "Weights" for the different means of transport are sometimes used for converting different vehicle types to Passenger Car Units (PCU).[104] Manual traffic counts normally should last 12 daylight hours. To get daily (24 hours) traffic, the 12-hours traffic would then normally have to be multiplied by a factor of 1.33. The Average Daily Traffic (ADT) would be calculated as the average of the seven days' count of the total daily "weighted" traffic.

Moving Observer Count (MOC)

MOC can be carried out by the evaluation team or by an inspector from the local government rural roads agency. The survey can be executed at any location of a particular road section but should last at least one hour. Utilizing the form proposed in this appendix, the different types of vehicles need to be put into three different categories: (a) vehicles traveling in the opposite direction (x); (b) vehicles overtaking observer (y); and (c) vehicles overtaken by the observer (z). Following will then be the hourly traffic in both directions (HT):

$$HT = (x + y - z) / t$$

(t = period of survey measured in hours). To convert the hourly flow into daily flows the following formula normally applies:

$$DT = 16 \times HT$$

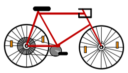
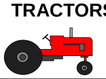
Manual Traffic Survey (MTS)

Manual traffic counts, using an adaptation of the form introduced in (1) above, should be used on all RTI network sections which are earmarked for upgrading to higher than basic access standard (including the upgrading from non-motorized basic access to motorized basic access). As mentioned in (2) above, a seven-day, 12-hour count is recommended. In particular circumstances, for example, in hotter climates where night travel is common, 24-hour counts might be warranted. It is important that both motorized and non-motorized traffic is counted and, in the case of non-motorized access only, obviously, human porterage must be counted as well. Seasonal variations might be important, and, if possible, counts should be conducted during various seasons of high- and low-traffic flows. Counts should be done far enough away from urban or village areas, so results are not distorted by local traffic activities.

Origin-destination (OD)-surveys, including trip purpose and duration of trips might be warranted in certain circumstances, especially if new RTI and major new alignments are planned. If overloaded trucks are prevalent, an axle-load survey might be required.

Rural roads agencies should carry out traffic surveys on all major sections of their network on a regular basis (at least annually). With experience, certain patterns will be established and time and efforts for individual surveys will be reduced. Such patterns include: typical seasonal variations, traffic composition, the share of night-time to day-time traffic, growth factors, and the correlation between traffic and villages size.

		COUNT MADE BY	
		CHECKED BY	
		SHEET	OF
DISTRICT		ROAD NO.	
SITE LOCATION		DAY	DATE

VEHICLE CLASS	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	Hrs:	COUNT	FACTOR	TOTAL	
BICYCLES 															X 0.2 =		a
CARTS: ANIMAL HAND DRAWN 															X 0.2 =		b
PASSENGER CARS 															X 0.5 =		c
LIGHT GOODS: PICKUPS SMALL BUS LANDROVERS OTHER 4WD 															X 1.0 =		d
TRACTORS 															X 1.0 =		e
MEDIUM + HEAVY TRUCKS 															X 2.0 =		f
BUSES 															X 1.5 =		g
TOTALS														Total = a….g		G	

• Manual Traffic Count to last 12 daylight hours • Average Daily Traffic (ADT) to be calculatedfrom average of 7 consecutive days	**REMARKS:**

Daily Traffic = DT = G x 1.33 = ______ **ADT = Average DT over 7 Days =** ______ **Date:**______________________

APPENDIX E
SAMPLES OF INNOVATIVE ECONOMIC APPRAISALS OF RTI INVESTMENTS

Appendix E.1
India - Andhra Pradesh
Rural Roads Component of Economic Restructuring Project

(Based on World Bank Infrastructure Note RT-5, January 2000, prepared by Liu Zhi)

Introduction

Rural road projects that aim to improve basic road accessibility from villages to markets and social services are expected to yield not only savings in vehicle operating cost (VOC) and road-user travel time cost (TTC), but also substantial social values in the form of broadened socioeconomic opportunities for the rural population. As most rural access roads have very low-traffic volumes, the social values generated from the improvement of basic access are often a more important item of project benefits than the direct road-user cost savings. Due to the difficulties in quantifying the social values in monetary terms, the road cost-benefit analysis methodology that quantifies road-user benefits mainly as VOC and TTC savings is unsuitable for evaluating rural basic access road projects. Alternative methodologies should be adopted. This appendix describes an application of cost-effectiveness analysis (CEA) to supplement cost-benefit analysis (CBA) in the evaluation and selection of road works for financing under a Bank rural road project in the state of Andhra Pradesh, India. An overview of the project is provided in a separate World Bank Infrastructure Note (Transport No. RT-4, January 2000).

An Overview of the Economic Analysis

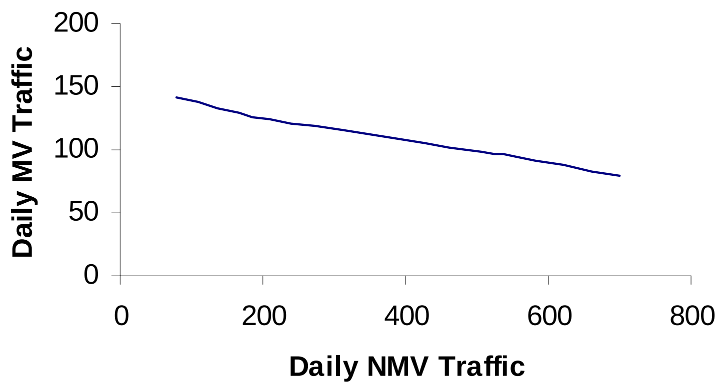
The project area includes three selected poor rural districts, Adilabad, Karimnagar, and Warangal, with a total population of 6.8 million. The project is proposed to improve the rural road network to at least basic, all-weather passable standard. The rural road network totals 15,000 km, most of which is in poor condition. Almost 60 percent of the network are tracks and earth roads, 10 percent gravel, and 30 percent water-bound macadam (WBM) roads. Neither tracks nor earth roads are all-weather passable. Both gravel and WBM roads can be all-weather passable, but many of them do not meet the all-weather standard due to broken or missing cross-drainage facilities. The role of economic analysis is to assist the design, prioritization, and selection of road works for financing under the project.

The demand for network investment greatly exceeds the project budget. The key to maximizing investment is focusing on the improvement of a core network that would ensure minimum connectivity for *each* village to a nearby main road or market center. The core network is identified through a rural road master planning process.[105] Its links that do not meet the basic all-weather standard are identified as candidate roads for improvement, and economic analysis is only applied to these roads.

Road works for candidate roads fall into two major categories: (a) *basic accessibility works*, including upgrading tracks and earth roads to gravel or WBM roads, and all minor and major cross drainage works on existing gravel and WBM roads; and (b) *black-topping works* on existing earth, gravel, and WBM roads. Since basic accessibility works are considered as a valuable instrument for poverty reduction, they are given first priority. Black-topping, on the other hand, is carried out primarily for economic reasons. When traffic volume (especially motor vehicle traffic) on an unpaved road reaches a certain level, it is more economical to pave the road rather than to keep restoring the unpaved road to all-weather condition. Economic justification is required for all black-topping works.

Both CBA and CEA methodologies are being used for this project. CBA is applied mainly to the black-topping works. A simple spreadsheet CBA program (shown in an attachment to this appendix), based on the conventional road CBA methodology, is first used to determine minimum traffic thresholds. These thresholds are defined as the combination of motor vehicle (MV) and non-motorized vehicle (NMV) traffic levels at which black-topping would be justified at the minimum economic rate of return (ERR) of 12 percent. They are shown as MV/NMV combinations along the curve in Figure E.1.1. All candidate roads with traffic levels around and above the thresholds are evaluated individually using the spreadsheet CBA program, and the ERRs are estimated. The candidate roads with traffic levels significantly below the thresholds are dropped from the list of black-topping works, but are considered for upgrading to basic access standard and evaluated in the category of basic accessibility works.

Figure E.1.1. ***Minimum Traffic Thresholds for Rural Road Paving***



Source: Authors.

CEA is applied to the selection of basic accessibility road works. All roads proposed for basic accessibility work are ranked by a simple cost-effectiveness measure—total population provided with basic access per $2,500 equivalent of expenditure. The top-ranking least-cost works are then financed, with a maximum of $50 equivalent per person served used as a final restrictive measure to ensure cost-effectiveness.

The economic analysis produces a list of basic accessibility road works ranked by cost-effectiveness and a list of black-topping works ranked by ERR. It should be noted that the application of CBA and CEA in this project does not deal with the optimal budget allocation between the two categories of road works. The allocation is decided through a stakeholder participatory process. Based on the budget allocation about 1,700 km of rural roads are selected for financing to basic accessibility standard, with a cost-effectiveness ratio ranging from $14 to $50 outlay per person served. A further total of 1,300 km of roads are selected for black-topping. Their ERRs range from 12 to 90 percent with an overall ERR of 24 percent. A total of 2 million people are expected to benefit from the project.

Village and Household Transport Survey

The application of CEA for basic accessibility works is supported by an assessment of the likely impact of basic road access on the welfare of rural households. Data was obtained through a small-scale rural household and village transport survey conducted for 40 sampled villages in the project area. For each sampled village, 10 households were randomly selected for the household level survey.

The survey results are summarized in Table E.1.1. below, which reveals significant differences in selected socioeconomic indicators between villages connected with all-weather access road and those unconnected. According to household interviews in the unconnected villages, poor road conditions, seasonal road closures, lack of motorized access, and the high cost of freight delivery are among the major obstacles to village accessibility. Moreover, road closure during the rainy season causes produce spoilage, delay of freight delivery, labor unemployment, and lower school attendance. When asked what impacts are expected from the improvement of roads, most households in both connected and unconnected villages responded with predictions of more seasonal work taken outside villages, higher intensity of cultivation, and expansion of cultivated land. The survey results provided strong empirical evidence to support the social and economic justifications for the provision of basic all-weather access to these villages.

Table E.1.1. ***A Summary of Rural Household Survey Results: Villages Connected with All-Weather Access Road versus Villages Unconnected, 1997***

Indicators	Connected	Unconnected
Household income ($/yr.)	700	275
Literacy rate		
Male	51%	40%
Female	35%	22%
Total	43%	32%
Avg. distance traveled for (km)		
Fertilizer	11	19
Seeds	11	19
Pesticides	9	16
Transport cost ($/ton-km)		
Fertilizer by bullock cart	0.13	0.33
Seeds by bullock carts	0.10	0.26
Fertilizer by lorry	0.16	0.25
Seeds by lorry	0.08	0.11
Avg. distance to school		
Primary education	0.2	0.2
Secondary education	2.5	18.0

Source: Authors.

The Spreadsheet CBA Program

The spreadsheet CBA program, shown in Table E.1.3, is designed specifically for the evaluation of rural road black-topping works. It has a conceptual structure similar to that of the HDM model, but is much simplified for rural road evaluation. The program consists of five panels. The first is used to record the road data and economic input parameters. The value of travel time is estimated using the rural per capita income data from the project area. The annual traffic growth rate is predicted based on the area's population and per capita income trends. The second panel contains engineering unit cost data obtained from the field. The third panel presents the estimated unit VOCs and travel speeds by both road type and vehicle type. The average road surface condition for each type of road in the project area is measured by a range of international roughness index (IRI).[106] The unit VOC data for motor vehicles are obtained from the empirical VOC-IRI relationships estimated for a Bank-financed state highway project in Andhra Pradesh, and extended to cover the worst IRI levels typically found on the rural road network. Average travel speed on each type of road surface is estimated by local engineers based on their field experience. The VOC-IRI relationships for bullock carts and bicycles are estimated using the NMV basic cost data (Table 2) collected from the field and the empirical relationships developed by recent studies in South Asia.[107] The fourth panel calculates savings in VOC and value of travel time (VOT) for the users of each mode of transport. Finally, the bottom panel calculates the economic cost and benefit streams over the project life, the net present value (NPV), and the ERR.

Table E.1.2. ***NMV Basic Cost Data, 1997***

Item	Unit	Bullock Cart	Bicycle
Vehicle price	US$	62.5	30.0
Price of a pair of ox	US$	312.5	n.a.
Annual cost of feeding the ox	US$/pair	150.0	n.a.
Annualized maintenance cost	US$	75.0	5.0
Vehicle depreciation	US$/yr.	12.5	5.0 (a)
Annual average usage	Km	2,400	1,000
Average year of life	Years	5	10
Average VOC per km	**US$**	**0.13**	**0.01**

Note: (a) Annual depreciation for the first three years
Source: Authors.

Lessons Learned

1. Where the provision of basic road access is mainly for social equity reasons, cost-effectiveness analysis can be used to evaluate or highlight the impact of the project, and economic efficiency can be considered implicitly through an emphasis on the least-cost design to achieve the project objectives.

2. The economic analysis described here requires systematic data collection. This particular experience may not be transferable to other rural road projects. However, one important lesson learned from this experience is that data collection at low cost can be possible with the active participation of the client in the preparation of the project.

3. Where systematic data do not exist or are costly to collect, effort should be made to at least establish a transport/poverty profile through a small-scale household survey, and to collect traffic data on the proposed rural roads.

4. While the methods used in this project help ensure the application of economic criteria, they do not deal with the optimal allocation of budget between the two categories of road works. This allocation should be decided through a participatory process.

Table E.1.3. ***Cost-Benefit Analysis Program for Rural Road Paving Project***

District name:	Warangal	Road name:	PWD to Chilpoor
Division name:	Warangal	Road No.:	L101
Road length (km):	15	Population served:	12,000
Current road type (enter 0 for earth, 1 for gravel, 2 for WBM)	2	No. of minor CD/km:	0.5
		Major CD (m/km):	1.0
Value of travel time (US$/hr)	0.06	Annual traffic growth rate	5%
Annual per capital income growth	3%	Standard Conversion Factor	0.90

Capital Cost ('000 US$/km)			Annualized Maint Cost ('000 US$/km)		
	Financial	Economic		Financial	Economic
Formation	5.00	4.50	Earth	0.55	0.50
Gravel (when available on site)	5.00	4.50	Gravel	0.68	0.61
WBM (each layer)	6.25	5.63	WBM	0.88	0.79
Blacktop	7.50	6.75	Blacktop	0.93	0.83
Minor CD ('000 US$/each)	5.00	4.50			
Major CD ('000 US$/m)	3.75	3.38			

	Unit VOC by Road Type (US$/km)				Travel Speed by Road Type (Min./km)			
	Earth	Gravel	WBM	BT	Earth	Gravel	WBM	BT
Vehicle Type	IRI=14-18	IRI=9-11	IRI=9-11	IRI=5-7	IRI=14-18	IRI=9-11	IRI=9-11	IRI=5-7
Buses	0.303	0.250	0.245	0.225	2.4	1.7	1.7	1.2
Mini buses	0.170	0.123	0.118	0.100	2.4	1.7	1.7	1.2
Cars/Jeeps	0.170	0.123	0.118	0.100	2.4	1.7	1.7	1.2
Trucks	0.343	0.280	0.268	0.240	2.4	1.7	1.7	1.2
Tractor Trailors	0.250	0.225	0.200	0.150	3.0	2.0	2.0	1.5
LCV/Tempo	0.170	0.123	0.118	0.100	2.4	1.7	1.7	1.2
Three wheelers	0.075	0.063	0.050	0.038	2.4	1.7	1.7	1.2
Two wheelers	0.063	0.038	0.038	0.025	2.4	1.7	1.7	1.2
Bullock carts	0.147	0.129	0.118	0.115	20.0	15.0	15.0	15.0
Bicycles	0.010	0.008	0.008	0.006	7.5	7.0	7.0	6.5
Pedestrains	n.a.	n.a.	n.a.	n.a.	17.0	16.0	16.0	15.5

	Base yr.	Avg. Veh.	VOC(US$/km)		Speed (Min./km)		Savings (US$/km)	
Vehicle Type	Traffic	Occup.	w/o. Proj	w. Proj.	w/o. Proj	w. Proj.	VOC	VOT
Buses	20	35	0.25	0.23	1.70	1.20	0.40	0.36
Mini buses	16	10	0.12	0.10	1.70	1.20	0.28	0.08
Cars/Jeeps	40	4	0.12	0.10	1.70	1.20	0.70	0.08
Trucks	24	0	0.27	0.24	1.70	1.20	0.66	0.00
Tractor Trailors	22	5	0.20	0.15	2.00	1.50	1.10	0.06
LCV/Tempo	37	1	0.12	0.10	1.70	1.20	0.65	0.02
Three wheelers	32	3	0.05	0.04	1.70	1.20	0.40	0.05
Two wheelers	68	1.5	0.04	0.03	1.70	1.20	0.85	0.05
Bullock carts	60	1.5	0.12	0.12	15.00	15.00	0.15	0.00
Bicycles	320	1	0.01	0.01	7.00	6.50	0.56	0.17
Pedestrians	680	1	n.a.	n.a.	16.00	15.50	n.a.	0.35
MVs (2 2w = 1 MV)	225		Annual sum (325 days/year) =				1868	400
NMVs	380							

		(All in thousand US$)				
Year	Traffic Growth	Capital Cost	Maint. Cost	VOC Savings	VOT Savings	Net Benefit
1998	5%	20.25	0.045	1.87	0.40	-18.03
1999	5%		0.045	1.96	0.43	2.35
2000	5%		0.045	2.06	0.47	2.48
2001	5%		0.045	2.16	0.51	2.62
2002	5%		0.045	2.27	0.55	2.77
2003	5%		0.045	2.38	0.59	2.93
2004	5%		0.045	2.50	0.64	3.10
2005	5%		0.045	2.63	0.69	3.28
2006	5%	6.75	0.045	2.76	0.75	-3.29
2007	5%		0.045	2.90	0.81	3.66
2008	5%		0.045	3.04	0.88	3.87
2009	5%		0.045	3.19	0.95	4.10
2010	5%		0.045	3.35	1.03	4.33
2011	5%		0.045	3.52	1.11	4.59
2012	5%		0.045	3.70	1.20	4.85
2013	5%		0.045	3.88	1.30	5.13
NPV						0.81
ERR						12.8%

Source: Authors.

Appendix E.2
Bhutan Rural Access Project: Economic Analysis[108]

Introduction

An IDA Credit for a "'Rural Access Project' in the Kingdom of Bhutan was approved by the IDA Board in December 1999. The main project objective is to improve access of rural communities to markets, schools, health centers and other economic and social infrastructure, in order to improve the quality of life and productivity of rural communities. The project will, among other things, help construct about 120 kilometers of rural access roads in four districts (dzongkhag) in Bhutan, where people have to walk an average of two days to reach the nearest road. Bhutan has good agricultural potential, but its villages are on the slopes of the Himalayan range, and a lack of access roads is a major socioeconomic problem. The Royal Government of Bhutan (RGOB) attaches great importance to improving rural access, as it will provide rural communities better access to markets, schools and health centers, and also help prevent rural-to-urban migration.

The note presented below is essentially Annex 4 of the Project Appraisal Document (PAD; IDA report no.19795-BHU, dated November 19, 1999). It summarizes the economic analysis of one project road, the Dakpai-Buli road (37 km), which is representative of the rest of the project. The case study presented is a first of its kind done in the Bank where an effort was made to quantify both social benefits and transport cost savings as part of the evaluation of improving rural access roads.

General Approach

A cost benefit analysis of the project investments has been carried out; its main assumptions and findings are summarized below. Since gathering socio-economic data for each project rural road for purposes of estimating its economic rate of return (ERR) is difficult and expensive, and since these are low-volume roads (less than 30 vehicles per day), the following methodology has been used: for one typical project road (such as the 37 km. Dakpai-Buli road which has the advantage of considerable area-specific socio-economic data collected and analyzed by the Netherlands funding agency NEDA under their integrated development project for the district), its ERR was estimated in detail based on quantification of social and economic benefits.[109] Based on this sample exercise, socio-economic norms and criteria were developed to test the viability of all other project roads.

Cost-Benefit Analysis of Dakpai-Buli Road

Project Benefits: The project roads will provide many types of benefits: (a) it will improve access to social infrastructure (schools and health centers), providing many benefits from increased education and health facilities and improved social interaction and mobility, which are important for social and economic development; (b) it will provide better access to markets by reducing transport costs, and by making it physically feasible for the first time to transport certain types of goods (such as construction materials), since the existing modes of mule transport and porterage are unable to handle such key capital inputs (for construction of houses, schools, small hydro-electric projects) and for general economic development; (c) it will improve the marketability of perishable goods through timely and cheaper transport, and this will provide a direct incentive for more market-oriented agriculture, with more profitable cash crops, and also raise rural income and employment; and (d) it will help isolated rural communities spread over the difficult mountain slopes of the country (home to 85 percent of Bhutan's population and 36 percent of its national income) to remain connected to the national economy. It will prevent their migration to urban areas that do not have the capacity to absorb them. Project impact in all these benefit-categories will be limited primarily to the project areas.

In what follows, an attempt is made to quantify some of the project benefits described above: (a) social benefits, (b) transport cost savings, and (c) agricultural benefits. Other benefits from industrial and regional development will be difficult to quantify and therefore no attempt is made to assess these impacts. A lack of data only permits a partial assessment, resulting in a conservative estimates of project economic return. The analysis focuses on one project road, the Dakpai-Buli road, as discussed above.

Social Benefits: A novel feature of the analysis is quantification of part of the social benefits (in addition to transport cost savings); we have made rough estimates of the value of better access to education which the road will provide, using Bhutanese data on enrollment levels with improved road access, and income levels of educated and uneducated persons. Improved road access (removing the present constraint of about 2 days' walking) will allow easy transport of children to schools, or schools may get located closer to the communities, leading to higher school enrollment levels, and improvement in the quality of schools. RGOB already plans on building new elementary and junior high schools following road construction when transport costs are reduced. Preliminary estimates, based on higher enrollment rates in the more accessible areas in the same district, indicate that about 75-100 children, would additionally go to schools every year if the road is built. More girls would attend because of proximity, and more boys would be released from the task of transporting goods. The life-time earnings of the educated versus uneducated samples provide an estimate of the income differentials. The net incremental income has been assessed after deducting estimated education and continuing education costs. This is attributable as net value added by the road since the additional enrollment would not have happened without the improved access provided by the road. Indeed education (especially education of girls) brings many more social benefits than income benefits, but we limited our estimate to incremental income from education. We have also estimated some health benefits (in reduced sick days, and reduced maternity and other deaths) attributable to improved access to health facilities, based on available local data. Overall, about 30% of the project benefits derive from quantifiable social benefits.

Box E.2.1. *Defining Accessibility in Bhutan*

It should be added that in a region where 2-3 days walking to the nearest road is usual, reducing this to even one day walking distance to/from a road is considered beneficial. Villagers have said that a distance of one day walking allows them to go to the road for sending produce by truck or for other services (often staying with relatives overnight), or for services such as health centers or community schools to be located within such villages. It was mentioned that a common practice is for school children to stay with relatives, if the road/school area is within at least a day's walking distance so that parents can visit them often with food and other supplies. Longer distance is considered too far for such purposes. We have therefore considered villages within a day's walking distance (say 25 km) as falling within the direct beneficiary zone of project roads

Source: Authors.

Transport Cost Savings: Basic traffic data estimates were supported by traffic surveys from the project area (particularly existing mule traffic, and household consumption patterns) conducted by local consultants. Estimates also used traffic growth data gathered during a feeder road project that was completed about five years ago in a similar area of the district. The current traffic level in goods (all traffic that is likely to shift to the road, currently moved as mule traffic or porterage) is about 10 tons per day, which is small. However, with road transport supplanting mule transport, traffic will increase. The estimates assume a traffic growth from about 10 vehicles per day (three trucks, two buses and five light vehicles/pick-ups) for the first year (2002) to about 22 vehicles per day in the fifth year, which is supported both by traffic demand (growth) in the area, and the growth pattern observed after road development in a similar area in the district. These may even be modest assumptions. The unit cost savings will be significant since the alternative cost of mule transport is very high, or about \$3 per ton-km (as field surveys and mule tariffs established). This is compared to an estimated trucking cost of about \$0.40 per ton-km (assumed high in this terrain).

The transport benefits have been calculated for the following four major categories: (a) transport savings on the normal growth of non-agricultural goods traffic assuming traffic levels without the road project (agricultural traffic is excluded since the benefits from transporting agricultural goods will be indirectly included in the estimate of incremental agricultural income); (b) transport savings on the induced non-agricultural goods traffic (additional non-agricultural traffic induced by the availability of the road); (c) transport savings on the normal growth of passenger traffic (persons traveling in the without road assumption; and (c) transport savings on the induced passenger traffic.

The unit cost savings are significant since the alternative cost of mule transport is very high, about \$3.0 equivalent per ton-km (as per field surveys and mule tariff established by RGOB), as against possible trucking cost of about \$0.4 per ton-km (assumed high in this terrain) after the road is built. For normal growth in existing traffic, the full reduction in costs is counted as project benefits; for induced traffic, only 50% of net benefits is counted as project benefits. Road transport benefits are assumed frozen at the level reached in 27th year since the road will reach saturation level of traffic at that time; the 27th year level of benefits is continued for the full road life of 40 years.

For normal growth in existing traffic, the full reduction in costs is counted as project benefits. For induced traffic, only 50 percent of net benefits is counted as project benefits. Road transport benefits are assumed frozen at the level reached in the 27th year since the road will reach saturation level of traffic at that time. The 27th year level of benefits is continued for the full road life of 40 years.

Using traffic growth data from a similar road constructed five years earlier in the same district and assuming similar traffic growth, total traffic was assumed (conservatively) to double in five years after completion of the road, reaching about 22 vehicles per day in year five. It is assumed to reach a level of about 100 vehicles per day in year 27. This projected traffic is an aggregation of all traffic (agricultural, non-agricultural, for existing, normal and induced growth).

Box E.2.2. ***Avoiding the Error of Double Counting Benefits***

The passenger traffic estimates are modest, since normally passenger traffic growth is found to exceed goods traffic growth in most cases. These figures exclude future bus traffic, if any, of children to/from schools or of people to/from health centers; since education benefits and health benefits are estimated separately on a different basis, we did not want to count their transport savings also as it would have meant double-counting of benefits; moreover such traffic is considered not significant. In the case of agricultural traffic, which is significant, the traffic was considered only for estimating road capacity/saturation levels, but their transport savings were excluded to avoid double-counting of benefits.

Source: Authors.

Agricultural Benefits: In terms of the agricultural benefits induced by the road, the estimate is based on a detailed analysis of the present cropping patterns in the area and the likely switch in cropping patterns to more profitable cash crops which will be facilitated by easier access to markets. A farm model with local production and cost co-efficients has been used for this estimate. It estimates the net value added in agricultural production due to reduced transport costs of farm inputs and output, and increased switch-over to cash crops (such as oranges, chilies, and other vegetables), based on similar experiences in other parts of Bhutan. It has been verified that apart from a marginal increase in extension services and the use of more fertilizers and improved seeds, no significant agricultural investments in land improvements would be required for the expected change to marketable crops. The net incremental benefits from agriculture (after meeting all additional costs of farming and transport) have been taken as benefits brought about by the road, since the absence of a road is the main bottleneck in producing more market-oriented crops in this area.

Project Costs

Road construction and maintenance requires major initial investments, followed by periodic maintenance costs. The Dakpai-Buli road is being built from year one (1999) to year three (2001). The first year of full road use is taken as year four (2002), ignoring interim benefits from the partial use of completed road sections. The stream of benefits and costs has been calculated for a 40-year period, (year 2002 to year 2041). This is justified since a well-designed mountain road with low traffic will last much more than 40 years if routine maintenance is done every year, and if periodically major repair works are undertaken. Adequate routine maintenance and a four-year cycle of periodic maintenance has been assumed in the cost stream to ensure a long life for the road. Moreover, Bhutan has a good past record on road maintenance, and community involvement in road maintenance is increasing, which will help sustain the road over a long life. For converting financial costs into economic costs, foreign components (mainly in construction costs) have been converted using c.i.f. (import) prices without adjustments; all other local costs and benefits have been converted into economic (border) prices using a factor of 0.9.

Overview of Results

Table E.2.1 summarizes the results of ERR analysis:

Table E.2.1. ***Net Present Value (NPV) of Economic Cost Benefit Streams (at 12 percent discount rate, in thousands of US$)***	
Cost of road investment and maintenance	3,817
Total Benefit attributable to the road	6,244
Transport benefits (non-agricultural traffic)	3,476
Net agricultural benefits	56
Net education benefits	1,699
Net health benefits	113
ERR (base case)	**15.1%**
Source: Authors.	

The main assumptions relate to higher school enrollment levels after road construction; traffic growth and transport savings; agricultural benefits; project life, and maintenance costs are described in the previous chapter.

Sensitivity Analysis / Switching Values of Critical Items: Varying the economic cost and benefit streams of the base case produces the following sensitivity table (Table E.2.2):

Table E.2.2. ***Results of Sensitivity Analysis***

Variations in Cost Stream	Variations in Benefit Stream		
	80%	100%	120%
80%	ERR 15.1%	ERR 16.9%	ERR 18.5%
100%	ERR 13.6%	ERR 15.1%	ERR 16.5%
120%	ERR 12.5%	ERR 13.9%	ERR 15.1%

Source: Authors.

Varying the economic cost and benefit streams produces the following switching values (at 10 percent and at 12 percent) for the ERR (Table E.2.3):

Table E.2.3. ***Switching Values***

Variations in Cost Stream	Variations in Benefit Stream		
	42%	61%	100%
100%	ERR 10.0%	ERR 12.0%	ERR 15.1%
162%			ERR 12.0%
237%			

Source: Authors.

The above figures show that the ERR estimates are robust, under varying pessimistic assumptions.

Assumption Regarding the Life of the Road: A separate sensitivity analysis was conducted with regard to the life of the road. The base-case ERR is based on a 40-year life of the road. This is a realistic assumption, because this is a well-designed mountainous road with low traffic—this road should have an even longer life. Moreover, adequate maintenance allocation has been made in the analysis. Bhutan has a good past record of satisfactory road maintenance, and local user community involvement in road maintenance is part of the project design and understanding with RGOB.

For life assumptions of 30 years and 20 years, the base-case ERR will decline to 12.9 percent and 10.1 percent respectively. As noted above, these reduced-life assumptions are not realistic. The results, however, highlight the need for good maintenance policies and practices to ensure viability of such road investments.

Applying the Dakpai-Buli Road ERR Analysis to the Total Project

Dakpai-Buli is considered typical of other project roads. The above analysis shows that the road produces an ERR of above 15 percent for 37 kilometers, costing about $3.6 million and serving about 8000 direct beneficiaries. This amounts to a per capita cost of about $450 in terms of project cost per beneficiary. Based on this, the per capita investment corresponding to 12 percent ERR is about $560. In other words, based on the Dakpai-Buli road impact analysis, a per capita investment per beneficiary of $560 (in 1999 prices mention the base price factor early in your narrative) is considered viable at 12 percent ERR.

In view of the difficulty of repeating such detailed studies for all the project roads, and since the access problems and economic conditions are similar in the service areas of other project roads, the norm of a maximum per capita (per beneficiary) cost of $560 is applied as an acceptable threshold for economic viability. These criteria will need to be satisfied for all project roads. The preliminary analysis for the other project roads shows that the per-capita investment for the remaining project roads will be less than $450, indicating a higher than 15 percent ERR, based on the Dakpai-Buli road norm of Dakpai-Buli road. This indicates that the overall Project ERR would exceed the 15 percent estimated for the Dakpai-Buli Road. More details are given in the project files.

Road Selection Criteria for Project Roads: Based on the above analysis, the following criteria (among others) have been agreed upon with RGOB for the selection of new roads under the project:

(a) Project roads must be part of the list of feeder roads included as priority roads in the ongoing Eighth Five-Year Plan. These road priorities have been decided upon on the basis of extensive participatory discussions involving local communities, district administrations, the Planning Commission and sector Ministries, and the King, who visited all districts for discussions on plan priorities with the local communities. They reflect a participatory, socioeconomic prioritization process, based on national economic and regional development objectives; and

(b) Based on the economic return calculations made for the Dakpai-Buli road, a per capita investment per beneficiary of $560 is considered viable at 12 percent ERR. All project roads should satisfy this criteria. The direct beneficiaries are estimated using the populations from villages that directly benefit from the project (defined as villages within one day's walking distance to or from project road). It can be increased by about 10 percent to include other beneficiaries who would directly benefit from trade with or visits to the newly accessible areas. (This was the procedure followed for the Dakpai-Buli Road). The road construction costs are to be calculated in 1999 prices, including 15 percent physical contingency.

Concluding Remarks

This case study presents an extreme case where (a) the road investment cost is very high at about $100,000 per kilometer, even for a one-lane gravel road (because of mountainous terrain and the decision to use environmentally friendly 'cut and fill methods'); (b) the number of beneficiaries per road is small due to sparse population density (about 8,000 direct beneficiaries); and (c) per capita investment is high, at about $450 per beneficiary (compared to below $100 in other countries).

The case illustrates that by attempting to carefully quantify the true economic costs of present transport bottlenecks, and the socioeconomic benefits which the investment will bring, the project could be justified. The use of realistic mule transport costs in the absence of the project, quantification of social benefits, and the use of realistic 40-year life assumption for the road, have all contributed to the viable ERR estimate, in spite of high investment costs. The 40-year life span assumption for the project road was endorsed by experienced road engineers, since it will be a well-built mountain road with relatively little traffic and good maintenance standards based on the good past road maintenance record of Bhutan.

The detailed studies carried out to assess the socioeconomic benefits were expensive, but can be effectively undertaken on a sample basis to establish an acceptable threshold of investment.

IDA Executive Directors, during Board consideration of the project, commended this new approach in assessing social benefits in rural road projects. The Quality Assurance Group of the Bank, which reviewed the project for quality at entry, also commended it for overall quality, including the innovative methods used in the economic analysis.

One lesson learned concerns estimating separate benefits from net value added in agriculture due to the switch to market-based crops after road construction. This was an elaborate procedure, using farm models from other parts of Bhutan where road availability has induced changes in cropping patterns. However, we later concluded that this exercise was not essential. The ERR estimates would have been almost similar if agricultural traffic was included as part of total traffic, and their benefits assessed using transport cost savings and reasonable traffic growth assumptions. This would have made the analysis much simpler and less time-consuming.

APPENDIX F
LOW VOLUME ROADS ECONOMIC DECISION MODEL (RED)

Introduction

The Low Volume Roads Economic Decision Model (RED) was developed under the Road Maintenance Initiative (RMI), a key component of the Sub-Saharan Africa Transport Policy Program (SSATP), to improve the decision making process for the development and maintenance of low-volume roads. The model performs an economic evaluation of road investments options using the consumer surplus approach and is customized to the characteristics of low-volume roads such as a) the high uncertainty of model inputs, particularly the traffic and condition of unpaved roads; b) the importance of travel time measurements to characterize the condition of unpaved roads and for model validation; c) the need for a comprehensive analysis of generated traffic; and d) the need to clearly define all accrued benefits. RED computes benefits for normal, generated and diverted traffic and takes into account changes in road length, condition, geometry, type, accidents and days per year when the passage of vehicles is further disrupted by a highly deteriorated road condition (wet season). Users can add other benefits or costs to the analysis, such as non-motorized traffic, social services and environmental impacts, if computed separately. The model is presented on a series of Excel 5.0 workbooks that collect all user inputs, present the results in an efficient manner, and perform sensitivity, switching values, and stochastic risk analyses. RED is available at the World Bank Road Software Tools Internet site:

http://www.worldbank.org/html/fpd/transport/roads/tools.htm

Sample Model Applications

Two typical RED applications are presented, which consist of the economic justification of surfacing a gravel road and justifying maintenance expenditures needed to maintain a certain level of service.

Surfacing a Gravel Road: A two-lane gravel road, with 200 vehicles per day, receives maintenance that consists of grading every 90 days and regravelling every 5 years, which yields a road with good passability and average roughness equal to 11.0 IRI. RED is used to evaluate the following project-options: (a) rehabilitate the road and improve the maintenance policy increasing the grading frequency to one grading every 60 days, (b) upgrade the road to surface treatment standard, and (c) surface the road with concrete blocks. The basic inputs are given in Table F.1 below.

Table F.1. ***Inputs for Example No. 1***

	Without Project	Project-Option 1	Project-Option-2	Project-Option 3
Description	Grading every 90 days	Grading every 60 days	Surface Treatment Surface	Concrete Block Surface
Average roughness (IRI)	11.0	9.0	3.5	5.0
Investment cost ($/km)		15,000	125,000	48,000
Maintenance costs ($/km/year)	4,200	4,800	1,000	2,400

Source: Authors.

Option 1 investment cost is the regravelling cost and options 2 and 3 investment costs are the paving costs, considering a 6.5 m wide surface treatment road and a 4.0 m wide concrete block road. The future maintenance costs needed to maintain the defined levels of service are estimated for each case. The analysis period is 10 years, discount rate is 12 percent and economic to financial costs multiplier is 0.85. The price elasticity of demand for transport is set to 1.0 for all vehicles, meaning that a one percent decrease in transport costs yields a one percent increase in generated traffic due to reduction in transport costs.

The results, given in Table F.2 below, show that options 1 and 3 are economically justified with a rate of return greater than 12.0 percent, while option 2 (upgrade the road to a surface treatment standard) is not justified, at the given discount rate of 12 percent, mainly to the relatively low traffic and high investment costs.

Table F.2. ***Results of RED Analysis***

	Option 1	Option 2	Option 3
Internal rate of return	24%	10%	33%
IRR sensitivity:			
Normal traffic x 0.75	15%	5%	24%
Investment costs x 1.25	18%	5%	25%
Maintenance costs x 1.25	15%	10%	31%

Source: Authors.

Rehabilitating the gravel road has positive economic benefits, but this option is fairly responsive to changes in the future maintenance policy, and the corresponding maintenance costs. Therefore, there should be some assurance that the road agency has the capacity to maintain the road before the rehabilitation is implemented. The option of surfacing the road with concrete blocks has the highest rate of return (33 percent) and under the sensitivity scenarios it maintains a high rate of return. Therefore, it is an economically robust option. This evaluation considers a 4.0 meter-wide concrete block road, but if one considers a 6.5 meter-wide concrete block road, at a cost of 78,000 $/km, the rate of return drops to 14 percent. A switching values analysis indicates that the daily traffic should be 180 vehicles per day to marginally justify a 6.5 meter-wide concrete block road and 90 vehicles per day to marginally justify a 4.0 meter-wide concrete block road. Note that these results are for a particular set of road user costs, traffic growth rates and condition of the road under the without project case. Therefore, the results can not be generalized.

Justifying Maintenance Expenditures: A two-lane earth road with 40 vehicles per day is in bad condition with average car speeds of 45 km/hour during most of the year and 35 km/hour during 30 days of the year (wet season). The road agency proposes to improve the level of service by eliminating the critical days and increasing the average car speeds to 55 km/hour during all year. The basic inputs are given in Table F.3 below.

Table F.3. ***Inputs for Example No. 2***		
	Without Project	With Project
Car speeds (km/hour)	45	55
Critical passability days	30	0
Car speeds during critical days	35	NA
Source: Authors.		

RED is used to evaluate the level of annual maintenance expenditures economically justified to achieve the proposed level of service. In the without project scenario, the road agency annual maintenance expenditures are $700/km per year for routine maintenance and one grading per year. RED finds that the maximum annual maintenance expenditures economically justified to achieve the proposed level of service is $3,400/km per year. The results, found in Table F.4, are the following.

Table F.4. ***Results of RED Analysis***		
	Without Project	With Project
Maintenance costs ($/km/year)	700	3,400
Internal rate of return (%)	NA	12.0%
Source: Authors.		

This means that that to achieve the level of service of 55 km/hour speeds all year, annual expenditures should not be more that $3,400/km per year for the given 40 vehicles per day. To achieve this level of service, the agency proposes a maintenance policy of routine maintenance, regravelling every seven years and three gradings per year, which amounts to $3,700/km per year. The proposed expenditures ($3,700) are higher than the estimated maximum economically allowable expenditures ($3,400), but the agency proceeds with the proposed policy because the difference ($300) is considered to be covered by the other social benefits not included in the analysis.

Conclusions

The model is easy to use, flexible, and requires a limited number of input data requirements consistent with the level of data collection needed for low-volume roads. The model is used to evaluate road investments and maintenance of low-volume roads and it estimates benefits to road users, to which other benefits can be added. Particular attention was given to the presentation of the results, highlighting all input assumptions. Because of the high variability and uncertainty regarding low-volume roads, emphasis was placed on the sensitivity, switching values and risk analysis.

NOTES

1. See Malmberg Calvo 1998.

2. Both under preparation. To be published in 2001.

3. Particularly for maintenance, the support of central government can rarely be relied upon. Exceptions are some road funds and other transfer mechanisms. See Christina Malmberg Calvo.

4. In some cases, at steep hills (see Appendix B) or where suitable gravel material cannot be found (as in Bangladesh), paving may be the most economical solution.

5. Often justified based on anticipated lack of maintenance and a lack of willingness to tackle this problem.

6. This approach is further elaborated upon in Chapter 4 and Appendix E.

7. Poverty Net: *http://www.worldbank.org/poverty/data/trends/index.htm*.

8. "Designated" means formal government responsibility or ownership has been established.

9. See Malmberg Calvo 1998.

10. Barwell 1996.

11. The authors estimate that of the 3 billion rural population in developing countries, 30 percent (900 million) are living in villages without reliable access, while 10 percent (300 million) are not provided with motorized access at all. To improve access to these people, an estimated $40 billion of investment and an annual $1 billion in maintenance would be required.

12. During the 1970s and 1980s many so-called integrated rural development projects were executed, supporting various sub-sectors. Most of them failed because they were not delivered in a manner consistent with national or local institutional and financial frameworks.

13. PAD Nepal Road Maintenance and Development Project 1999.

14. PAD Bhutan Rural Access Project 1999.

15. Rural household survey conducted in preparation of the Rural Roads Component of the Andhra Pradesh Economic Restructuring Project 1997.

16. Pankaj 1999.

17. Adapted from World Bank 1996a.

18. Volume I (Malmberg Calvo) was published in 1998. Volume II is this paper. Volumes III and IV are planned to be published in 2001.

19. For example, see the Comprehensive Development Framework (CDF) or Poverty Reduction Strategy Papers (PRSP) at: *http://www.worldbank.org/*

20. "Rural Transport Projects: Concept Development, Justification, and Appraisal," a lecture series given by Prof. John Howe at the World Bank, September 20-24, 1999.

21. Intermediate means of transport not only include non-motorized means of transport (NMT) such as bicycles and animal drawn carts, but also appropriate low-cost motorized means of transport such as scooters and single-axle tractors.

22. See Barwell 1996.

23. For example, see Malmberg Calvo 1998.

24. Geoff Edmonds (1998): *Wasted Time: The Price of Poor Access.*

25. Avoiding some transport needs altogether, for example, through improved communications, is a promising and cost-effective alternative.

26. Refer to Education Advisory Services, World Bank.

27. The topic is being addressed in a World Bank Technical Paper entitled "Developing Rural Transport Policies and Strategies," planned for publication in 2001.

28. Often projects "assign" responsibilities to communities (in the absence of local government capacity) which exceed their capacity in the long-run, or which are too complicated to manage (for example, links that provide access to several villages). This is often done instead of the necessary, but difficult, task of promoting capacity building at local government and community levels.

29. See Malmberg Calvo 1998.

30. For example, in Ghana, rural roads are managed by the Department of Feeder Roads of the Ministry of Roads and Highways in collaboration with local governments. Similar arrangements exist in Bangladesh and India.

31. This will require a one-hour walk from the village to the most remote part of the community road and one hour back, which reduces the available effective work time for maintenance to six hours. However, in countries with a low population density, community RTI is often much longer than five km (which often means that roads are not affordable).

32. See Note 21.

33. In some countries, such as France, access is stated as a fundamental human right in the constitution.

34. Many roads are being upgraded to higher standards at (despite negative rates of return) or (despite dubious measurements of their development effectiveness and economic profitability), Therefore, the potential for the reallocation of resources to basic access exists. However, if real transport bottlenecks are observed (such as congested or heavily deteriorated high-traffic roads), these can be economically very costly and need to be addressed in priority.

35. As in the case of Bangladesh where non-motorized rickshaw-vans (for goods) and passenger rickshaws dominate traffic.

36. In the rare cases where transfer arrangements from central budgets or road funds exist for financing RTI maintenance, local communities must still provide substantial contributions. This is one of the main reasons for local level ownership through a participatory approach to planning, monitoring and evaluation for this type of intervention.

37. Some empirical evidence from recent World Bank projects (see Appendix E) suggests that the limit of what can be afforded in terms of RTI investment is close to the annual per capita GDP of the population served.

38. If a country is not maintaining its main road network, it is also unlikely to be maintaining its secondary road network and new public investments should be avoided.

39. For example, in Burkina Faso the existing path network (that provides access to all the rural households) has been estimated at 112,000 kilometers. If this network would be developed to roads and added to the existing road network of 16,000 kilometers, the road density of Burkina Faso would be comparable to that of a developed country with similar population density.

40. See Note 11.

41. See Notes 13, 14 and 15.

42. For example, in Burkina Faso, Gnanderman 1999, found that there are about 112,000 km of paths versus 16,000 km of roads.

43. Normally designed for ten or twenty year flood levels.

44. Up to a traffic range of 50-150 VPD, “full access” will normally require a gravel road of one-and-a-half lanes (carriageway width of 4.5 to 5.5 meters), while above 150 VPD, a two-lane road will be appropriate (6 meters carriageway with shoulders). The provision of a bituminous sealed surface (double/triple surface dressing or OTTA seals) is usually only justified at traffic levels of above 200 to 400 vehicles per day, depending on terrain, rainfall, and soils. In India, the “standard” full access rural road is a single-lane road with a carriageway width of 3.6 meters, a formation width of 7.5 meters, and a surface layer of 40

cm consisting of a 2 cm bituminous layer on a triple layer of water-bound macadam and a gravel layer costing a total of $40,000 equivalent per kilometer.

45. "Road Building in the Tropics," TRL 1993.

46. See Note 41.

47. In India, the policy is that rural road closures should not exceed 12 hours per event and not more than 15 days per year in total. In most francophone African countries, the road agencies operate rain barriers on rural roads. Normally, the rule is that these barriers must be closed during heavy rains and at least four hours thereafter. In Nepal, due to the severity of the monsoon season and the high cost of permanent river crossings, most roads other than the national highways and urban roads are seasonal access roads that are closed for about three months during the monsoon season.

48. However, in the USA, about 40 percent of the approximately 6 million kilometer road network are gravel or earth roads and are in their majority single-lane (Highway Statistics 1998, Federal Highway Administration).

49. See Richard Robinson.

50. For example, new lending instruments, such as the World Bank's Adaptable Program Lending programs, allow for a longer-term performance-based approach to project lending.

51. For example, the SRR (Structures on Rural Roads) component of the first and second Rural Roads and Market Improvement Projects of the World Bank in Bangladesh, and the Morogoro Road Support Project assisted by the Swiss Development Cooperation in Tanzania.

52. The National Transport Program Support Project, 2000. Also see, Asif Faiz et al. TRB Record.

53. However, a "phased" approach can be recommended, as practiced in the "Green Road Approach" in Nepal, where first a trail is constructed and then gradually expanded to a road, particularly in a mountainous environment.

54. For example, see Heggie and Vickers 1998.

55. As demonstrated by Ellis and Hine, "a road with traffic of 10 vehicles per day has 0.05 conflicts per day at a speed of 40 km/h. This will increase to 1.3 conflicts per day at a volume of 50 vehicles per day."

56. Although encroachment into existing alignment is a situation encountered frequently.

57. For environmentally friendly RTI design, see Appendix B, particularly the chapter on bio-engineering.

58. OP/BP/GP 4.01 Environmental Assessment and OP/BP/GP 4.30 Involuntary Resettlement; *Roads and the Environment*, WB Technical Paper 376, 1997; and *Managing the Social Dimension of Transport. The Role of Social Assessment*. World Bank, Social Development Web site.

59. For example, the "Destitute Women Program" implemented in Bangladesh.

60. Good guidelines for the training of small scale contractors can be found in a ILO publication: *Capacity Building for Contracting in the Construction Sector*.

61. See Stock and de Veen 1996.

62. See Bentall, Beusch and de Veen 1999.

63. See Malmberg Calvo 1998.

64. See Larcher 1999.

65. See MART Working Papers Nos. 1 to 14.

66. World Bank. 1994. *Bank-Financed Projects with Community Participation: A Manual for Designing Procurement and Disbursement Mechanisms*. Africa Technical Department, Washington, DC.

67. As a rule of thumb, expenditures for maintenance should be 50-80 percent of total expenditures for roads in a growing network and 90-95 percent in a mature network.

68. See Malmberg Calvo 1998.

69. In Burkina Faso, for example, the systematic execution of grading operations in combination with spot recharging of gravel has greatly reduced the need for periodic regravelling.

70 Hine, J and Cundill, M. "Economic assessment of road projects: Do our current procedures tell us what we want to know?" International Workshop On Impact Evaluation and Analysis of Transportation Projects In Developing Countries. Bombay, December, 1994.

71. Tsunokawa and Hoban 1997; Beenhakker 1987; Chapter 4, Handbook of Economic Analysis in Transport Project Work.

72. For more on participatory approaches see World Bank, Social Development web site: <u>*http://www.worldbank.org*</u> – Topics and Sectors – Social Development.

73. For further information on participatory planning tools see Malmberg Calvo 1998.

74. For more information on participatory techniques see World Bank Participation Source Book, 1996.

75. A good example are the guidelines and Thana Planning Handbook prepared by the Local Government Engineering Department (LGED) in Bangladesh.

76. A low-cost survey should assess the existing level of access and determine the types of interventions necessary to secure basic access. A small team (driver, engineer, local foreman) with vehicle should be able to survey around 40km/day of roads, or 20km/day of paths on foot or by means of IMT.

77. Basic access is understood here as defined in Chapter 3 and elaborated in Appendixes B and C.

78. For example, in the province of Saskatchewan in Canada, wheat farms are based on square mile lots. Along the perimeter of the lot, there is normally a public access road from which a penetration road leads to the farm house. When selecting which of these access roads should be gravelled (which means the provision of costly “crusher-run” material because the in-situ soils are mainly clays) it has been decided that, per farm, only one access road to the main road system (and normally the shortest one) is being gravelled (and therefore becomes an all-season road) while the others remain seasonal earth roads. This is an example of a “basic access” approach that has been applied in a developed country.

79. World Bank, OP 10.04 1994.

80. Normally, life cycle costs should be used in this formula (including maintenance). However, in this case, maintenance costs were found to be uniform over the network and there was no need to consider them..

81. The cost of upgrading of all link that cost less than $50 per person served would exhaust the available budget.

82. For a further discussion, see Gannon and Lebo 1999.

83. The producer surplus (PS) method has been widely applied throughout the developing world, especially where road improvements are intended to increase agricultural value added. This method was codified in the work of Carnemark, Biderman and Bovet (1976), and later expanded and simplified by Beenhakker and Lago (1983).

84. For example, see Padeco (1996), Non-Motorized Transport (NMT) Modeling in HDM-4, Draft Final Report for Transport Division of the World Bank. Also see World Bank (1996), Bangladesh, Second Rural Roads and Markets Improvement and Maintenance Project, Project Implementation Document No. 15, Economic Appraisal of FRB Roads, South Asia Regional Office, World Bank.

85. For additional information on valuing travel time savings, see Gwilliam 1997.

86. See Cook 1990.

87. R. Ahmed and M. Hosain, Development Impact of Rural Infrastructure in Bangladesh. International Food Policy Research Institute (IFPRI) in collaboration with Bangladesh Institute of Development Studies (BIDS), 1990.

88. World Bank. 1999. Project Appraisal Document—Kingdom of Bhutan, Rural Access Project. South Asia Regional Office, Washington, DC.

89 As elaborated in Chapter 3 of this paper, basic access roads provide all-season access (within certain limits) to the prevailing vehicles. Traffic levels on basic access roads are less than 50 motorized, four-wheeled vehicles per day, but often there is a substantial amount of NMT.

90. TRL Road Note No. 6: *A Guide to Geometric Design* and TRL publication: *Road Building in the Tropics*.

91. Paige-Green, P and A Bam. *Passability criteria for unpaved roads*. Research Report RR 91/172, Department of Transport, South Africa, 1994; also Ellis, SD and JL Hine. *Rapid appraisal techniques for identifying maintenance priorities on low volume rural roads.* Unpublished Project Report PR/OSC/122/97, Transport Research Laboratory, 1998.

92. An equivalent laboratory test would be an unsoaked CBR of 15 percent with modified proctor compaction.

93. See Box B.1

94. *A Guide to Geometric Design*, TRL Overseas Road Note 6, Transport Research Laboratory, Crowthorne, 1988 defines the three categories as follows:

    Level (0 to 10 five-meter ground contours per km): Level or gently rolling terrain with largely unrestricted horizontal and vertical alignment.

    Rolling (11 to 25 five-meter ground contours per km): Rolling terrain with low hills introducing moderate levels of rise and fall with some restrictions on vertical alignment.

    Mountainous (greater than 25 five-meter ground contours per km). Rugged, hilly and mountainous with substantial restrictions in both horizontal and vertical alignment.

95. *Principles of Low-Cost Road Engineering in Mountainous Regions*, TRL Overseas Road Note 16, Transport Research Laboratory, Crowthorne, 1997.

96. Bridges are normally designed to accommodate annual high flows without excessively restricting flow or incurring damage either to the structure or surrounding land. A high flood which may only occur once in every 100 years may cause damage to approach embankments but should not damage the superstructure. See: *A Design Manual for Small Bridges*, Overseas Road Note 9, Transport and Road Research Laboratory.

97. Nepal 1997.

98. National Research Council, Washington DC, 1993. *Vetiver Grass, a Thin Line Against Erosion.*

99. Clark, J., and J. Hellin. *Bio-engineering for Effective Road Maintenance in the Caribbean.* Natural Resources Institute, Chatham. 1996.

100. Bentall P., A. Beusch and J. de Veen 1999.

101. Extracted from Stock A., and J. de Veen 1996.

102. ATBrief 8, Improving Paths and Tracks in *Appropriate Technology*, Vol. 21 No. 1, gives more details on these approaches.

103. Wagner et al. 1992. *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas*, Volumes A to E, SKAT. Switzerland.

104. These "weights" are based on the standard measure of road capacity, Passenger Car Units (PCU), an approach applied on higher-category roads, which allows consistent comparison of traffic throughout the network. However, for RTI where traffic capacity is not usually an issue, the merit of this conversion is not clear.

105. For details on the rural road master planning process, see World Bank Infrastructure Notes, Transport No. RT-4, January 2000.

106. While the appropriateness of using IRI for rural road project evaluation remains debatable, for this particular project, it is judged appropriate by the project team, given the substantial differences in roughness found among different types of rural road and the relative uniformity within each type of rural road in the area.

107. (1) See PADECO (1996), *Non-Motorized Transport (NMT) Modeling in HDM-4*, Draft Final Report for Transport Division of the World Bank. (2) World Bank (1996), *Bangladesh: Second Rural Roads and Markets Improvement and Maintenance Project: Project Implementation Document No. 15: Economic Appraisal of FRB Roads*, South Asia Regional Office, World Bank.

108. The main economic analysis and report was done by a team consisting of Thampil Pankaj, and Eddy Bynens, with considerable support from Kynghkhor consultants of Bhutan who conducted various field studies and some of the analysis. The study received valuable guidance from Frannie Léautier, and support and advice from Juan Gaviria and other Bank colleagues. The detailed study is available from the World Bank's Rural Roads Thematic Group Web site at *http://www.worldbank.org/html/fpd/transport/rt_over.htm*.

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