APPENDIX A

ROAD NETWORK, MOBILITY AND ACCESSIBILITY IN SELECTED COUNTRIES

(where available, data are 1998)

Country (1)	Area (2)	Pop. (3)	Pop. Density (4)	GDP per Capita (5)	Main Road Net-work (6)	Local Road Network (7)	Total Road Network (8)	Of which Paved (9)	Road Density (10)	Road Net-work/ Pop. (11)	Road Asset Value (RAV) (12)	RAV/ GDP (13)	Maint. Exp./ Capita (14)	Vehicle Owner-ship (15)	Pers.-km (16)	Pers.-km/ GDP (17)	Access -ibility (18)
	Thousand square km	Millions	Pop. per square km	$	Thousand km of national and regional/ state/ provincial roads)	Thousand km of local government & community roads	Thousand km	Percent	Km of road per square km of land area	Km of roads per thousand persons	Billion $	Road Asset Value as % of GDP	Required vs. actual maint-enance expenditure in $ per capita	Number of cars, buses and trucks per thousand persons	Km traveled per day per person; road and rail	Person-km divided by GDP in $	% of pop without all-season motorable road within 1-2 km of household
Low-Income																	
Burkina F.	274	11	39	243	10	6	16	12	0.06	1.5	2.1	79	5 / 1	5	0.8	1.2	17
Chad	1284	7	6	233	6	34	40	1	0.03	5.7	1.9	116	7 / 1	3	0.2	0.4	75
Ethiopia	1104	61	61	106	20	9	29	15	0.03	0.5	4.2	65	2 / 1	1	n.a.	n.a.	60
Ghana	239	19	81	405	15	23	38	24	0.16	2.0	3.5	45	5 / 2	7	n.a.	n.a.	20
Guinea	246	7	29	507	12	18	30	17	0.12	4.3	2.8	79	10 / 2	5	n.a.	n.a.	30
India	3288	980	330	439	1496	1823	3320	46	1.01	3.4	336	78	9 / 3	10	5.8	2.1	22
Nepal	147	23	160	210	5	7	13	31	0.09	0.6	1.0	21	1 / 0.5	3	0.2	0.3	40
Nigeria	924	121	133	343	63	73	136	27	0.15	1.1	14	34	3 / 0.2	11	4.1	2.9	10
Tanzania	945	32	36	249	28	60	88	4	0.09	2.8	6.8	85	5 / 2	4	n.a.	n.a.	30
Middle-Income																	
Brazil	8547	166	20	4691	265	1400	1665	10	0.20	10.0	161	21	20 / 14	76	15	1.2	9
Latvia	65	2	40	2667	20	39	59	39	0.91	29.5	12	226	120 / 34	241	n.a.	n.a.	3
Namibia	824	2	2	1824	14	50	64	8	0.08	32.0	8.5	233	85 /21	78	n.a.	n.a.	30
Peru	1285	25	19	2528	17	57	74	12	0.06	3.0	11.4	18	9 / 3	118	9.7	1.4	25
Romania	238	23	98	1698	15	185	200	68	0.84	8.7	16.8	43	15 / -	135	n.a.	n.a.	5
Russia	17075	147	9	1883	531	40	571	-	0.03	3.9	269	97	37 / -	153	n.a.	n.a.	5
S. Africa	1221	41	34	3225	233	301	506	34	0.41	12.5	132	100	64 / 15	137	45	5.1*	20
Tunisia	164	9	60	2151	14	9	23	79	0.14	2.6	7.5	39	21 / -	63	n.a.	n.a.	5
High-Income																	
Germany	349	82	235	26012	140	517	657	99	1.88	8.0	383	18	- / 93	529	30	0.4	0
Japan	377	126	336	29926	187	965	1152	75	3.06	9.1	567	15	- / 131	560	29	0.4	0
Sweden	412	9	21	20608	97	114	211	78	0.51	23.4	217	116	- / 150	468	33	0.6	1
USA	9159	270	30	30449	1394	4954	6348	59	0.69	23.5	3779	46	- / 101	780	55	0.7	1

* The unusually high ratio of person-kilometers per GDP in South Africa is related to the forced separation policies (and the resulting commuting needs) of apartheid.

Sources: Columns 2-5: World Bank, World Development Indicators Database. Columns 6-9, and 15-16: International Road Federation, World Road Statistics 2000, data 1994-98 (where available). Remaining columns: data from country-specific studies and own estimates and calculations. Column 12 (RAV): RAV was calculated as follows: (a) low-income countries: col. 6: $200,000/km, col. 7: $20,000/km; (b) middle-income countries: col. 6: $500,000/km, col. 7: $50,000/km; (c) high-income countries: col. 6: $2,000,000/km, col. 7: 200,000/km. Column 14: actual amounts are from IRF World Road Statistics or from World Bank project information; the required amounts were calculated as a percentage of the asset value, as follows: for low-income countries: 2.5% of RAV; for middle-income countries: 2.0% of RAV. Column 16 includes only movements by motorized means of transport. Column 18 represents rough estimates based on expert knowledge

APPENDIX B
DESIGNING BASIC ACCESS ROADS

General

This appendix provides guidance on the design of basic access roads.[89] Further guidance to the topic can be found in the literature.[90]

The design of motorized basic access necessitates a return to the guiding principles of highway engineering. Determining the minimum interventions necessary to ensure passability at least cost requires a thorough understanding of the complex interactions of soils, terrain, climate, and traffic. Moreover, creating sustainable solutions to the problems posed by these interactions requires a significant level of engineering judgment, technical skills, and local knowledge.

Standard solutions are often insufficient. Terrain conditions can vary considerably within countries and between regions. Traffic types and needs depend on the circumstances of individual communities. To achieve cost-effective basic access, it is important to tailor interventions to the specific situation and not to impose rigid designs. However, there are a number of basic engineering standards that should be adhered to, and these are summarized in Table B.1 below.

The supporting notes are not intended to present a comprehensive design procedure, but to supplement good engineering practices with low-cost solutions not normally included in conventional highway manuals.

Table B.1. ***Basic Access Road Standards for Various Terrain***

Feature	**Terrain**		
	Flat	**Rolling**	**Mountainous**
Carriageway width	3.0 meters	2.5 to 3.0 meters	2.5 to 3.0 meters
	If shoulders are insufficient to allow passing of the prevailing vehicles, passing places of 20 meters length must be provided every 200 meters. Parking place for buses and trucks will be required in villages and towns.		
Formation width	3.5 to 5.0 meters	3.0 to 5.0 meters	3.0 to 4.0 meters
Minimum curve radius	12 meters	12 meters	8 meters
Road surface type (in-situ material unless otherwise stated)	Gravel on weak soils	Gravel or stone paving on steep sections or weak soils	Gravel or stone paving on steep sections or weak soils
Camber	5 to 8%	5 to 8%	3 to 5%
Maximum gradient	N/A	12%	12 to 15%
Water crossings	Concrete or stone drifts. 600mm diameter culverts. Vented fords for major crossings. Single-lane submersible or high-level bridges where water flow is substantial and perennial.		
Cross-sections and Side drains	Road required to be about 50 cm above flood level	Scour checks	Lined drains >10%

Source: Authors.

Soils

Only limited research has been carried out on the mechanisms that cause unpaved roads to become impassable.[91] This research has concluded that there is no significant correlation between soil characteristics and overall road passability. However, there does exist a significant correlation between passability and the adequacy of the drainage provision.

A significant percentage of a basic access road should be able to utilize the existing in-situ soils. However some soils, even if well compacted and drained, are still too weak to resist shearing under the intended traffic load, or may be too slippery for steep gradients (for example, black cotton soils).

The following thresholds are therefore proposed, below which motorized roads should be provided with a gravel or similar running surface:

- In-situ materials should demonstrate a minimum California Bearing Ratio (CBR) of 15 percent at prevailing moisture conditions.[92]

- In areas other than flat terrain, the shrinkage product (SP)[93] of the surface material should not exceed 365.

Based on international experience with soil types, the following guidelines (Box B.1) can be considered for preliminary appraisal. However, the findings should be carefully scrutinized at the design stage.

Box B.1 ***Design Considerations for Different Soil Conditions***

Laterite—In general, lateritic soils can be successfully used for the formation of low-volume traffic roads. If the material is close to a mechanically stable particle-size distribution, then it performs well as a surface material for low-volume traffic roads. Soil of this quality frequently occurs in-situ and hence, gravelling is not required. Suitable rock for crushed aggregate is often scarce in tropical areas where weathering is usually intense and lateritic gravel is normally used instead. The clay and silt content is often high and as a consequence, makes the road surface slippery during rains. Temporary closing of laterite roads during rainfalls is advisable.

Tropical alluvial—In general, alluvial soils can also be used for the formation of low-volume traffic roads. In principle, alluvial soil makes a good surface material. However, alluvial deposits are normally stratified with a uniform particle size in the single stratum. It is therefore necessary to mix layers with different grain sizes to achieve a well-graded gravel.

Volcanic ash—Ash soils in areas of persistent high volcanic activity are highly sensitive to disturbance and therefore should not be use for road construction. In areas where the annual cycle includes hot dry seasons, ash soils transform into halloysitic soils (commonly called "red coffee" soil). Low-traffic roads can be constructed using this soil. However, the material becomes very slippery during rains and if the road is not gravelled, it might be advisable to close the road during rainfalls. Over-compacting of halloysitic soils should be avoided as this makes the soils weaker and more susceptible to the effect of moisture.

Expansive clays—Using expansive clays to build roads in temperate climates poses few problems. A gravel surface needs to be added onto a well-draining camber to avoid penetration of surface water into the formation material. In tropical climates, black cotton sections should be avoided as much as possible.

continued…

…Box B.1 continued

Where this is not possible, it is advisable to raise the road above the surrounding level and to provide wide and shallow ditches. Two layers of compacted gravel surface are required. In addition, the shoulders should be covered (haunched) with the gravel course in order to avoid any rainwater penetrating the surface and weakening the formation material. Expansive soils in tropical climates can severely erode if adequate protection measures are not taken, especially in ditches with slopes greater than 2 percent, culvert outlets and embankment slopes.

Desert soils—Wind-blown sands dominate and are often single-sized material, which makes it difficult to compact. At the same time, there is hardly sufficient water available for effective compaction. Sand alone should not be used as road-surface material and needs to be sealed or covered with an adequate surface material, such as seal, gravel, or calcrete. It is often difficult to find suitable gravel as surface material. Calcrete has been tried in a number of cases (such as Botswana, Namibia) with good results, but can be difficult to extract by labor-based methods.

Source: Authors.

Terrain

The terrain through which a road or track leads can conveniently be classified as flat, rolling, or mountainous, defined by both subjective descriptions and average ground slope.[94] The terrain type has considerable impact on the nature of the drainage, alignment, road structure, performance after construction, and ultimately, costs.

Recommendations for basic standards applicable to each terrain category are set out below for rolling terrain, very flat, and very steep conditions.

Rolling Terrain: Rolling terrain is the most commonly encountered terrain type. Whereas existing tracks in this terrain are normally motorable for the majority of their length, there often are distinct problem areas that make access difficult. Bearing-capacity problems are more prevalent on level sections or shallow grades, while slipperiness problems tend to occur on steeper grades. These sections need careful inspection in determining where imported soils or gravel surfacing are required.

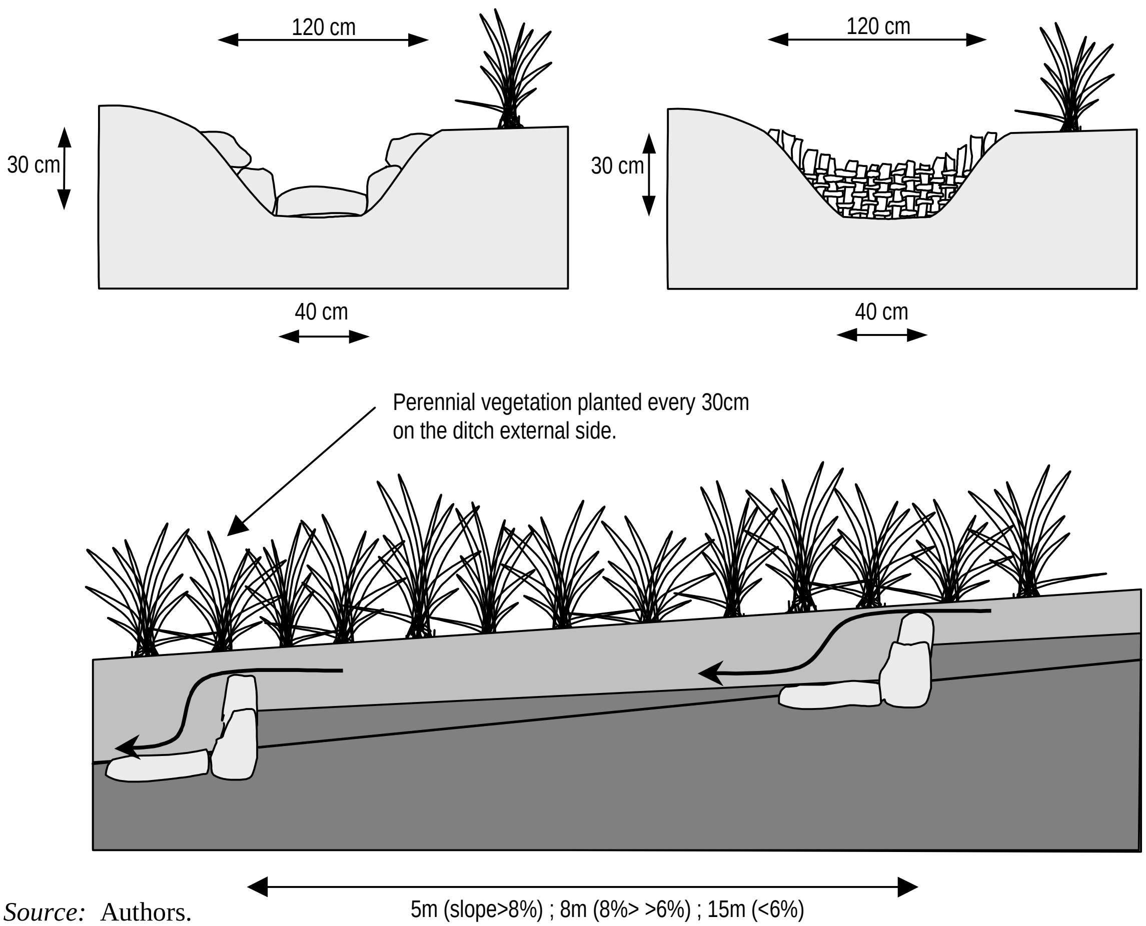
Typically, the existing alignment will have developed naturally over time to connect villages by the most direct route, possibly following non-motorized transport routes that avoid minor obstacles. Therefore, it may be necessary to realign short sections to avoid steep grades and overly tight curves for motorized traffic. However, finding an alternative alignment is relatively straightforward in this terrain.

Drainage provision is the most important aspect, and all existing cross-drainage points will require inspection and treatment. The solution may be as simple as a stone-surfaced “splash,” but work must always be done to ensure that the road is not cut by erosion as a consequence of heavy runoff. Up to five splashes, drifts, or culverts may be required in a typical kilometer of road. All structures and drainage outlets must be securely protected against erosion.

Runoff from the road surface must be quickly diverted to adjacent land to avoid ponding and softening. This may not require side drains throughout, but the road surface must be correctly shaped with adequate camber or cross slopes. Although 5 percent is usually specified for engineered roads, 8 percent has been found to perform better on low-traffic earth and gravel roads.

Where side ditches are provided, they must be equipped with scour checks if the gradient exceeds 4 percent and mitre drains every 20 meters to protect against erosion (Figure B.1).

Figure B.1. ***Typical Scour Checks***



Source: Authors.

Basic access roads in rolling terrain are single lane with a carriageway width between 2.5 and 3 meters. The total formation width should be between 3 and 5 meters. The wider formation allows light vehicles to pass at low speeds if the shoulder can be driven on.

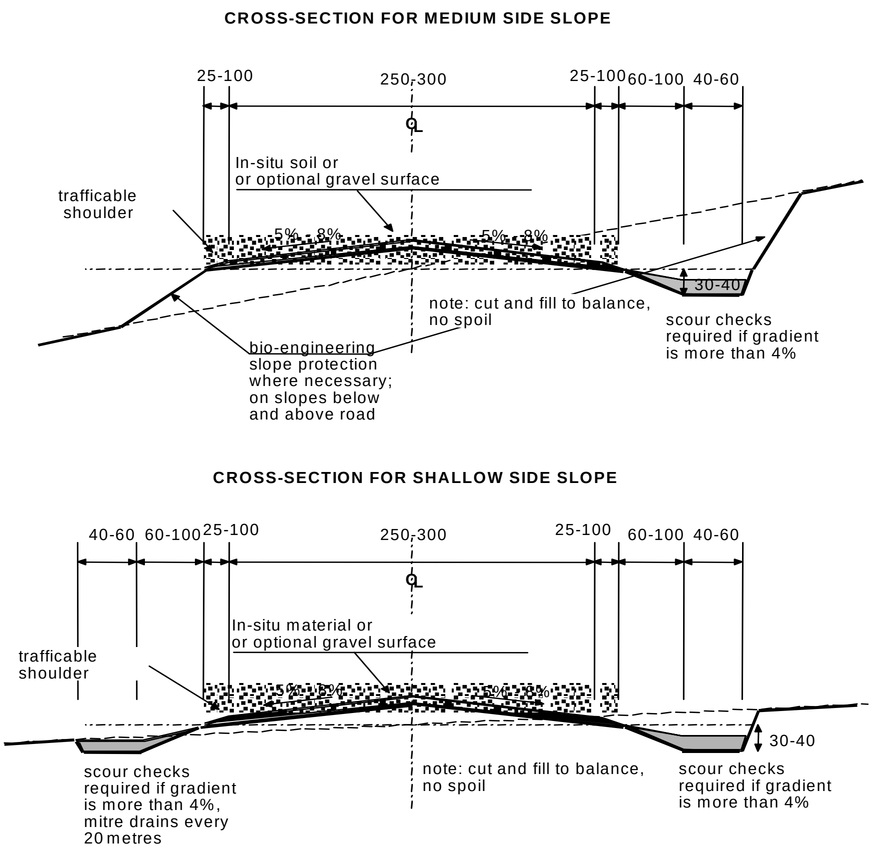
However, sufficient passing places (bypasses) at suitable places (minimum every 200 meters) have to be provided. The width of the carriageway at these passing places should be at least 5 meters. The length of the passing places must be a minimum of 20 meters.

The absolute minimum horizontal radius for curves is 12 meters. This is just within the minimum turning radius of small commercial vehicles and buses. If much larger vehicles are expected and required, the road geometry must be amended accordingly, but this would not normally be expected on basic access roads. The most important issue is to ensure that the geometry is consistent. Long, straight sections and shallow high-speed curves must not be followed by unmarked tight curves. This would be hazardous for motorized traffic, and even more so for the pedestrians they may encounter.

The longitudinal gradient should not exceed 12 percent. Sections with a gradient greater than 10 percent should always be gravelled and possibly be considered for paving (see alternative pavement options in chapter 4 of this appendix). It may be necessary to gravel more shallow gradients depending on the erosion-resistance properties of the in-situ soil. This can only be determined by on-site inspection.

Typical cross sections for improvement work are shown in Figure B.2 below. Where side slopes are greater than 4 percent, it is only necessary to provide side drains on one side of the road.

Figure B.2. ***Rolling Terrain Standard Cross-Sections***



Source: Authors.

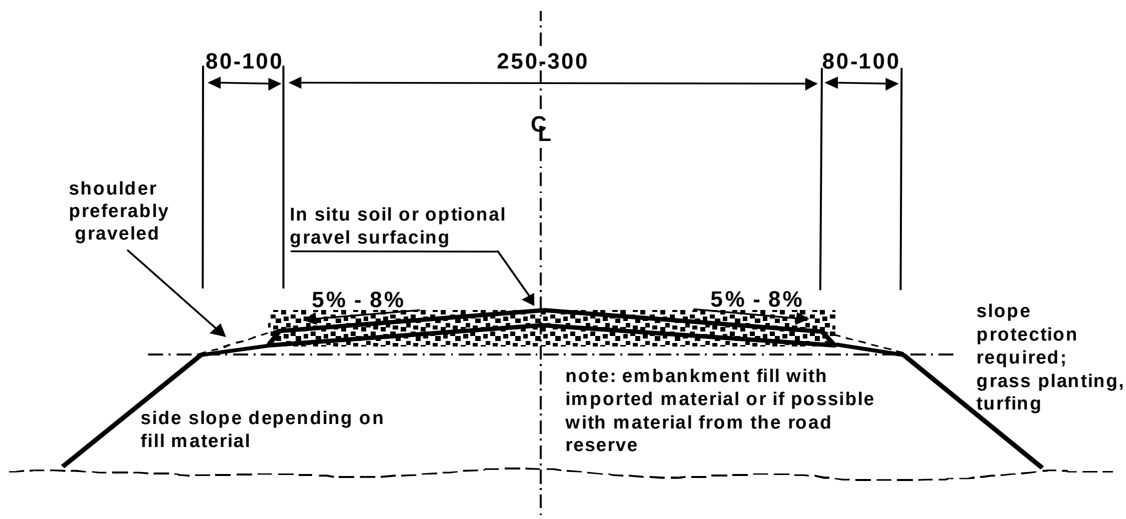
Flat Terrain: The location of existing tracks on flat terrain can be very seasonal. Traffic tends to take the most direct line in dry periods, and circumvent trouble spots as they occur in the wet season. Before a fixed route is established, it is essential to carefully study the drainage patterns and quantify the impact. Even relatively minor works can create a dam with associated erosion in periods of high rainfall. Drainage structures must be sufficient to ensure that flood flows can pass unimpeded. This may require submersible structures for areas with short flood periods, but require high-level bridges in areas with significant flooding.

In low-rainfall areas, the typical cross-section is similar to that of rolling terrain. However, in high rainfall areas it is necessary to elevate the road above flood level to maintain access. A freeboard of 0.5 meters above flood level is usually sufficient to ensure that the road surface does not lose its strength. Material can be used from adjacent land, but such embankments usually need surfacing with imported material. In these circumstances, spot improvement is not a feasible option.

Embankment widths may be up to 6.5 meters, which is wider than that applied in rolling terrain, to allow for possible softening of the edges during flood conditions. A minimum gradient of 1 percent should be applied, if possible, to all side drainage to avoid ponding. In seasonally flooded areas however, side drains have limited usefulness. A typical embankment section is shown in Figure B.3 below. Since the natural material may be highly erodible, building protection with natural materials becomes a priority activity. The embankment slope must be matched to the stable angle of the prevailing material.

Material for the embankment should not be excavated directly along the embankment foot, as this allows water to penetrate the fill. Borrow-areas or trenches should be located at some distance from the embankment (10 meters). These borrow-areas should be excavated to be as shallow as possible, and after the construction, they should be reinstated (slopes made shallow, topsoil brought back and vegetation planted). In agricultural areas, excavation planning should be carried out in participation with farmers to optimize location and methods. This will also ensure that the borrow places are best utilized (such as, for fish ponds, rice paddies, and so forth).

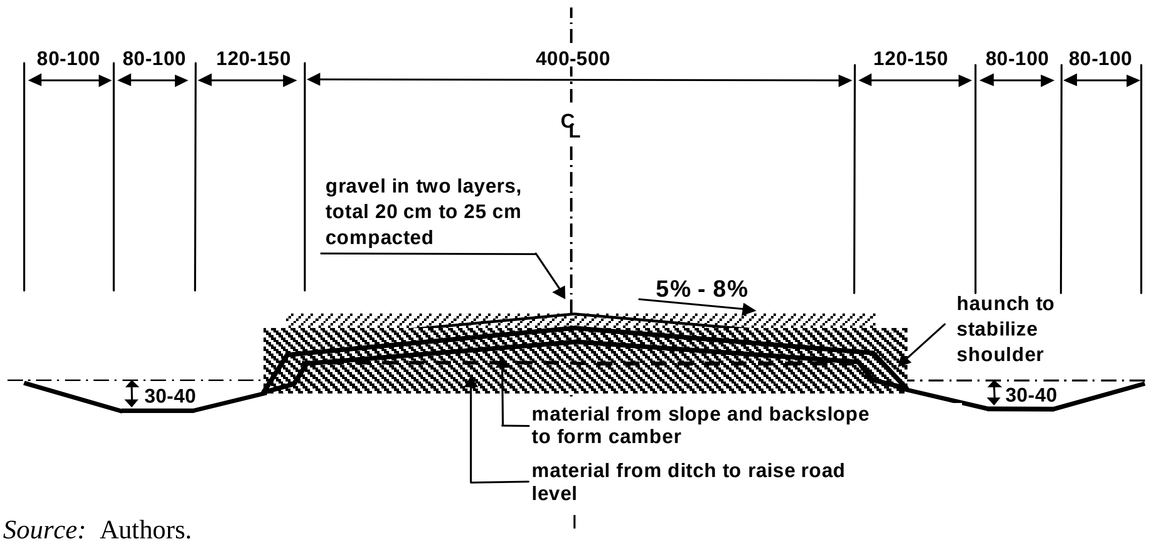
Figure B.3. ***Flat Terrain: Embankment Cross-Section***



Source: Authors.

Expansive clays, often termed black cotton, present a formidable problem that will always need special treatment (expansive clays occur in all terrain types, but are more prevalent and difficult to circumvent in flat terrain). For low-traffic levels, the cross-section shown in Figure B.4, below, usually provides sufficient strength.

Figure B.4. ***Flat Terrain: "Black-Cotton" Cross-Section***



Source: Authors.

Mountainous Terrain: Existing tracks in hilly and mountainous terrain have usually evolved along foot or pack animal trails. Common risks include excessive gradients and tight curves on hairpin bends, causing vehicles to carry out reversing maneuvers in dangerous circumstances. A significant amount of realignment can be expected in this terrain, requiring a full reconnaissance of alternative routes. However, it is possible for experienced surveyors to determine adequate routes by field survey using handheld instruments (such as GPS, abney level).

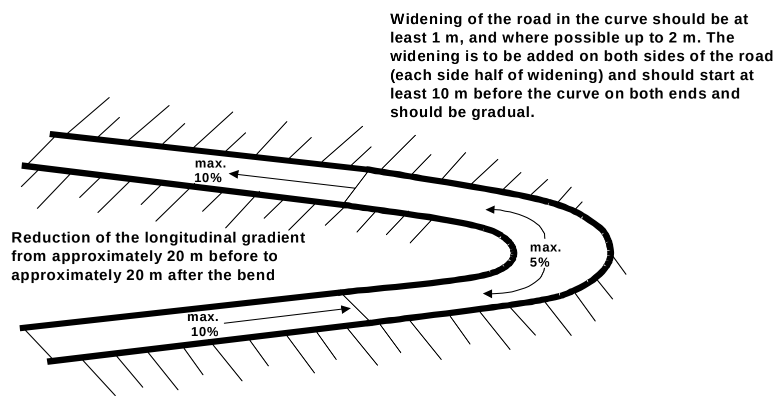
To minimize the costs associated with designing basic roads for this terrain, standards may be reduced to the absolute minimum in terms of road width and maximum gradients. However, the road must remain passable to the typical traffic in the area. The minimal standard for a single lane would be a carriageway width of 2.5 meters. Total formation width should be between 3.0 and 4.0 meters.

Sufficient passing places at suitable sites should be provided. The minimum spacing should be 200 meters, or more frequently where vision is restricted. Carriageway width and length at the passing places should be a minimum of 5.0 and 20.0 meters, respectively.

The absolute minimum horizontal radius for curves is 8.0 meters. Widening the curves may also be required to increase the visibility of oncoming traffic. This is a particular problem where steep-cut faces restrict sight distance. The curve widening should be between 1.0 and 2.0 meters depending on the nature of the curve and site conditions. The maximum gradient in curves should not exceed 5 percent.

In general, the maximum gradient should not exceed 15 percent. Sections with a gradient greater than 10 percent should be considered for paving (see alternative pavement options in chapter 4 of this appendix). Hairpin bends need to be carefully set out with respect to both curvature and gradients to ensure that the anticipated traffic can negotiate them without danger (Figure B.5).

Figure B.5. ***Mountainous Terrain: Construction of Hairpin Bends***



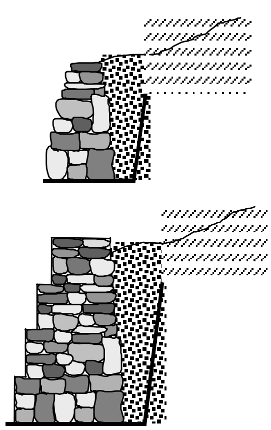
Source: "Low Cost Road Construction in Indonesia, Labor-Based Road Projects in Manggarai District, Volume 1, Intercooperation," by A. Beusch, P. Hartmann, R.C. Petts, P. Winkelmann.

Special attention must be paid to slope stability. Existing alignments are usually fairly stable, and problem areas are obvious. However, new alignments can precipitate slip failure on uphill cut-faces, and create severe erosion problems downstream of drainage outlets. Considerable care must be taken with stabilization measures. Even relatively small landslides can block these small mountain roads. The TRL guidelines on mountain roads contains a considerable amount of information in this area.[95]

Bio-engineering approaches, utilizing appropriate plants to solve structural and environmental problems, have proven very cost-effective in recent projects in Nepal. These sustainable methods are both labor-intensive and replicable for rural areas (see Chapter 6 of this appendix).

Retaining walls are required on both the valley and mountain side depending on the stability of the material, especially where vegetation cannot stabilize the slopes (Figure B.6). Retaining walls should be constructed using dry masonry for heights up to 4 meters and gabion walls for heights above 4 meters or where there is increased earth pressure. Cement-bound masonry should only be used where absolutely necessary.

Figure B.6. ***Mountainous Terrain: The Construction of Retaining Walls***



- **dry stone retaining walls for heights up to 4 m**
- **crown width minimum 1 m**
- **slope face 3:1**
- **stone filter at back of wall**
- **weep holes 20 cm above ground, at every 2 m to 3 m**

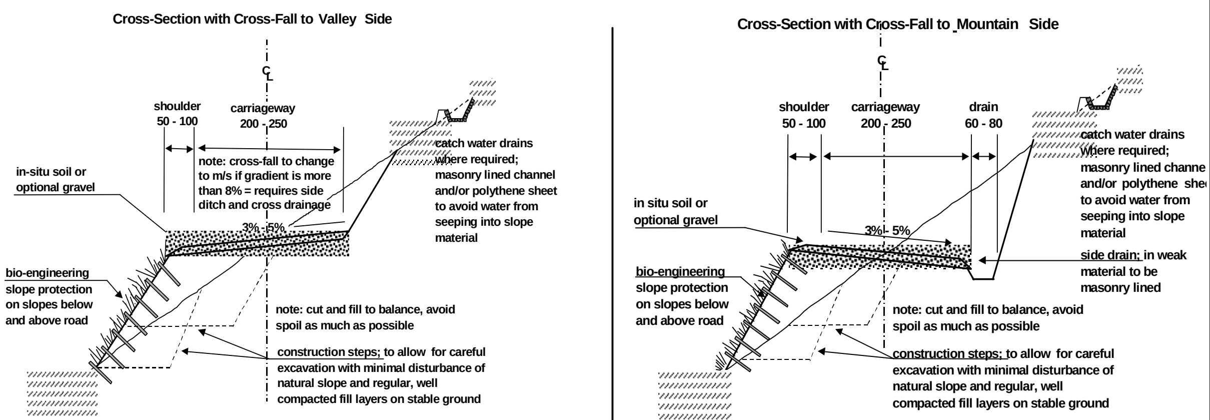
- **gabion retaining walls for heights more**
- **stone filter at back of wall (check design details and dimensions in relevant manuals)**

Source: Authors.

Drainage structures can be similar to those adopted in rolling terrain. Protection of the outfalls is critical and may need to be taken well beyond the road reserve, possibly for the entire drop to the valley floor. Gully erosion related to drainage outfalls is causing severe environmental damage in many rural areas.

Two typical mountain road cross-sections are shown in Figure B.7 below. These use alternative approaches to the problem of dealing with drainage and minimizing costs. Advantages and disadvantages of the two approaches are given.

Figure B.7. ***Mountainous Terrain: Alternative Cross-Sections***



Advantages

–no side drains required, resulting in substantial reduction in earthworks
–less cross-drainage structures required
–evenly spread surface water runoff along road edge reduces erosion problems

Disadvantages

–potentially dangerous for vehicles sliding when surface slippery
–careful maintenance of surface required to ensure water drains evenly over shoulders
–when gradient exceeds 8 percent, cross-fall must be changed to mountain side

Advantages

–safer for vehicles in wet and slippery conditions
–wider formation improves site distance
–critical outside edge of road less prone to damage
–controlled surface drainage outlets

Disadvantages

–more earthworks because of the increased width to accomodate drainage
–higher back slopes requiring protection
–frequent cross-drainage structures required
–more expensive

Source: Authors.

Alternative Pavement Options

Alternative pavement types may be required for roads or road sections where the in-situ material or gravel does not provide the required quality surface. This may be the case on steep sections exceeding 10 percent, sections passing villages, or simply where the in-situ soils are too weak and gravel is not available or too expensive. Some of the available options for paving are discussed in Box B.2.

Box B.2. ***Paving Options***

Stone Paving (see also Figure B.8)

Description	Natural stones measuring no more than 20 to 30 cm are laid on a 5 cm sand/gravel bed with the top surface set to the final cross-fall. The large stones are set with the wider face to the bottom. Empty spaces are filled with smaller stones and firmly wedged into place. Compaction is carried out with a vibrating pedestrian roller. The surface is then sealed with a gravel-sand-clay mixture and the finished paving is compacted again.
Uses	• Surface for low-traffic roads • Base for urban roads • Base for low-traffic roads which would require upgrading to asphalt standard if the traffic level is likely to increase beyond the economical threshold of gravel and stone-paved roads
Characteristics	• Labor-based construction method • Use of locally occurring materials • Ease of maintenance
Traffic	• For low-volume roads as surface • All traffic categories as a base
Cost	Comparable with gravel surfacing if stones occur in road locality
Life	Stone paving can have a very long life if maintained properly. Resealing should be done an average of every three years. Stones broken out of the pavement or damaged edges should be replaced immediately in order to avoid costly repairs

Clay or Concrete Brick Paving

Description	Burnt clay or concrete brick (200 x 100 x 80 mm approximately) laid on a thin layer (about 4 cm) of clean sand, on a conventional road base.
Uses	• Surface for low-traffic roads, especially short sections • Surface for urban roads, where speeds are below 50 km/h
Characteristics	• Labor-based construction method • High load-carrying capacity • Reusable surfacing and can have high local resources component • Ease of maintenance
Traffic	• For low volume as surface for short sections • From residential streets to heavy industrial application
Cost	Competitive with asphalt concrete in Europe where labor costs are high. Potential for significant cost savings in developing countries.
Life	Initial life 20 years and more, reusable bricks and blocks

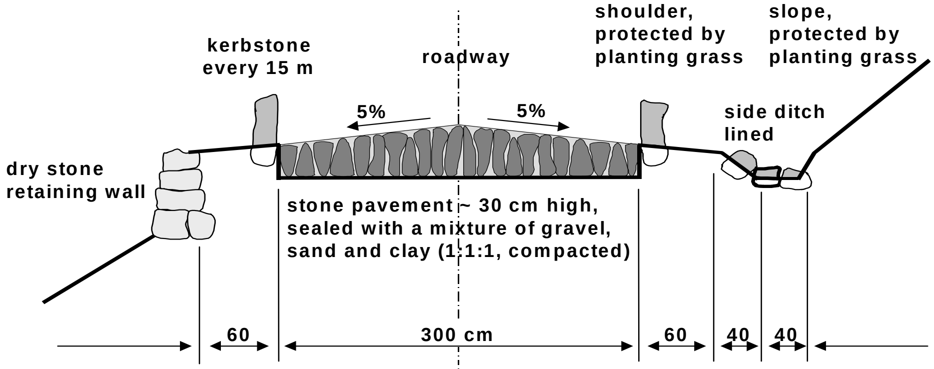
Bituminous Surface Dressing

Description	A thin film of bitumen applied mechanically or by hand onto the road surface and covered with a layer of stone chipping, then lightly rolled.
Uses	• Surface for low-traffic roads and for short sections • Surface for urban roads (Multiple coats may be applied if circumstances warrant)
Characteristics	• Permits labor-based construction method • Provides durable dust-free running surface • Provides waterproof pavement seal and arrests surface deterioration • Allows for ease of maintenance
Traffic	• Can be used for all traffic categories
Cost	Inexpensive: typically 25% of the cost of an asphalt concrete surfacing. On average $1 to $2 per square meter and coat.
Life	Typically five to 15 years in a tropical environment

Source: Authors.

Slurry seal, hand-mixed asphalt, and stone sets are additional options that also may be applicable for very-low-volume situations where gravel is scarce.

Figure B.8. ***Typical Cross Section for Stone-Paved Road***



Source: Authors.

Water Crossings

Water crossings are the most essential and potentially the most expensive intervention to secure basic access. The conventional solution is usually a clear-span low-maintenance structure of steel or reinforced concrete on substantial abutments for river crossings, and pre-cast concrete pipes or box culverts for lower flows, designed to accommodate flood flows under all conditions other than exceptional events.[96] However, this is often not an affordable solution and for basic access, it is necessary to explore other options.

One option is the use of timber bridges on masonry, gabion, or reinforced earth abutments. This provides considerable savings on initial costs and maximizes the use of local skills and resources. However, it is only viable where suitable timber is readily available and spans are usually limited to six meters. There is also the likelihood of high maintenance costs and a short life span if the timber is not insect- and rot-resistant (either naturally or through special treatments).

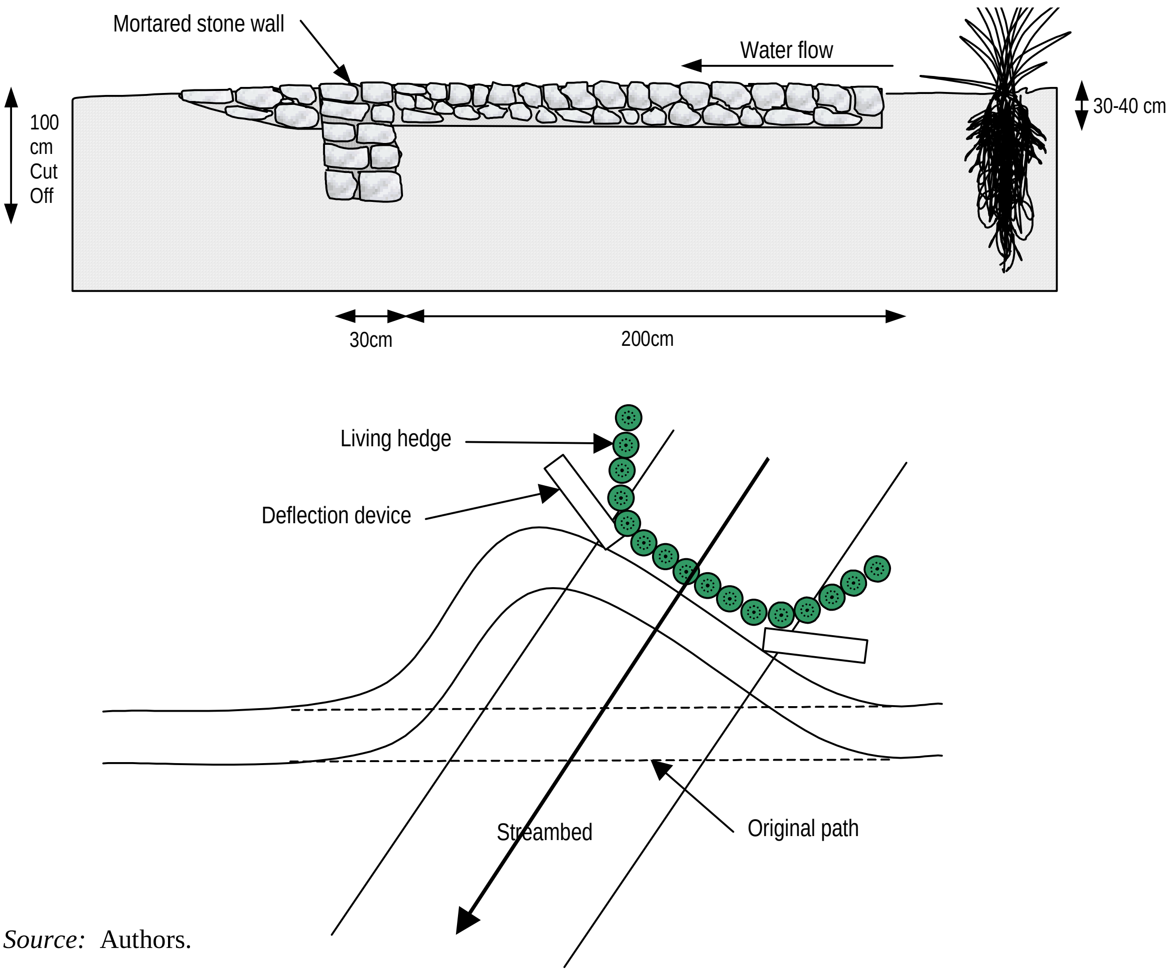
Another option is to build a structure that can easily be overtopped without damage. These options include drifts and vented drifts. The decision should be based on flow patterns and community usage. Small rivers and streams in tropical regions are often wet-weather flow only, and high-flood levels are of short duration. A simple drift is usually adequate to secure vehicle access in these circumstances. For continuous flows, vented drifts can be designed to pass normal discharge, only submerging during floods.

It must be remembered that foot and non-motorized traffic constitute a significant portion of the traffic on basic access roads. Consideration should be given to providing safe passage for pedestrian and bicycle traffic. On long single-lane bridges, railings and a one-side elevated foot and bicycle path should be considered. Where submersible structures are frequently and deeply submerged, the provision of a separate low-cost footbridge might be considered.

Thorough site investigations and hydraulic design are necessary not only for large structures but also for relatively small structures on low-volume traffic roads. Figure B.9 shows some options for drainage structures appropriate for labor-intensive implementation by small-scale or community contracts. Their design needs to be adapted to the local conditions, including locally available materials and skills.

Drifts: These are the simplest structures available and are easy to maintain. They can be built of stone or concrete. Care should be taken to ensure that they are not scoured by the drainage flow. They must also be shaped to avoid damage to low ground-clearance vehicles.

Figure B.9. ***Simple Stone Masonry Drift***

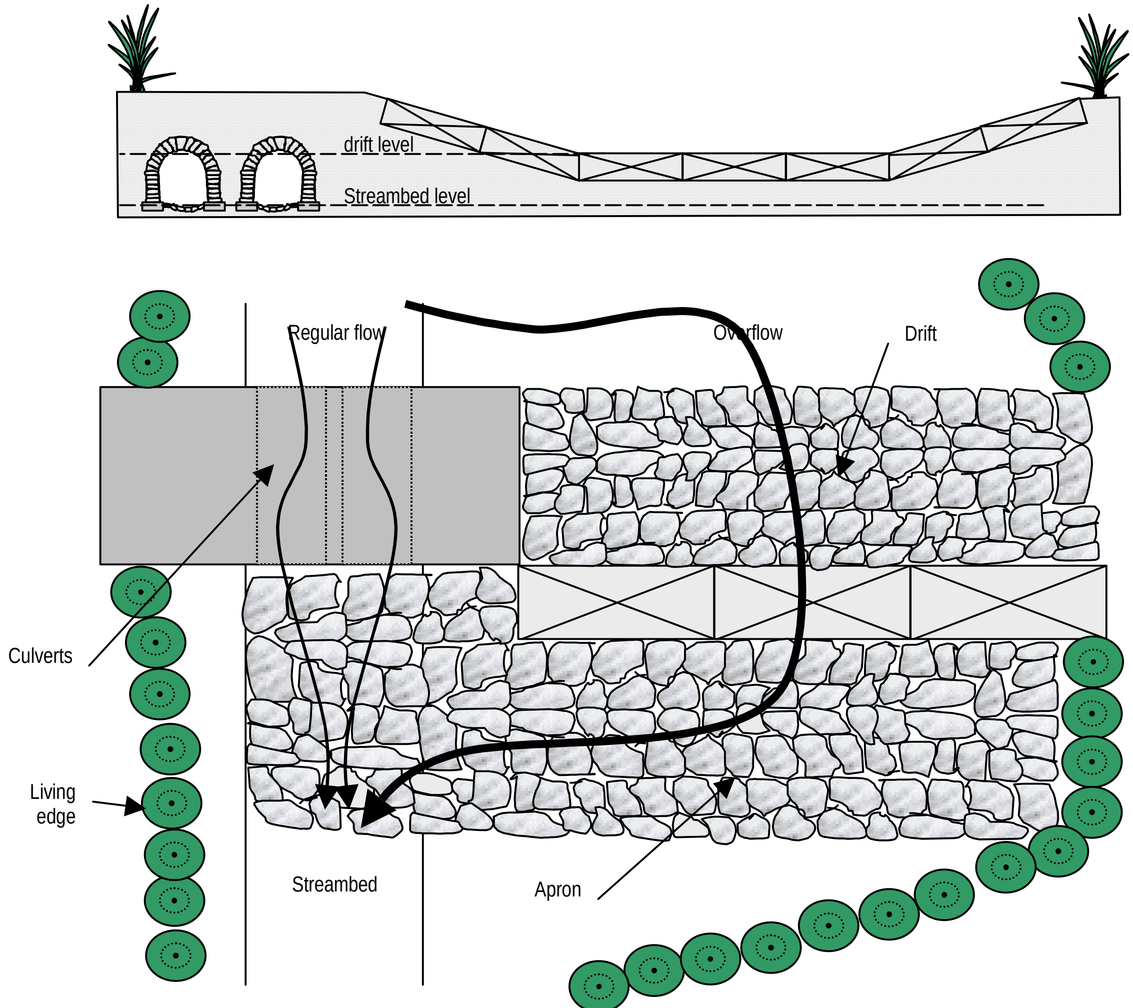


Source: Authors.

Vented Drifts: Vented drifts allow dry passage in periods of low flow, but act as drifts in periods of high flow. It is important to ensure that the structures are well anchored to the streambed, as there can be significant uplift when partly submerged. They are also easily blocked by debris and require attention after every flood. A downstream scour apron is also essential.

In some situations, flood levels may be very high. Flood posts must be provided to indicate water levels to prospective traffic. There are many recorded cases of fatal accidents in these situations. A very simple vented drift is shown in Figure B.10 below, where masonry arch culverts are combined with a masonry drift "overflow."

Figure B.10. ***Vented Drift***



Source: Authors.

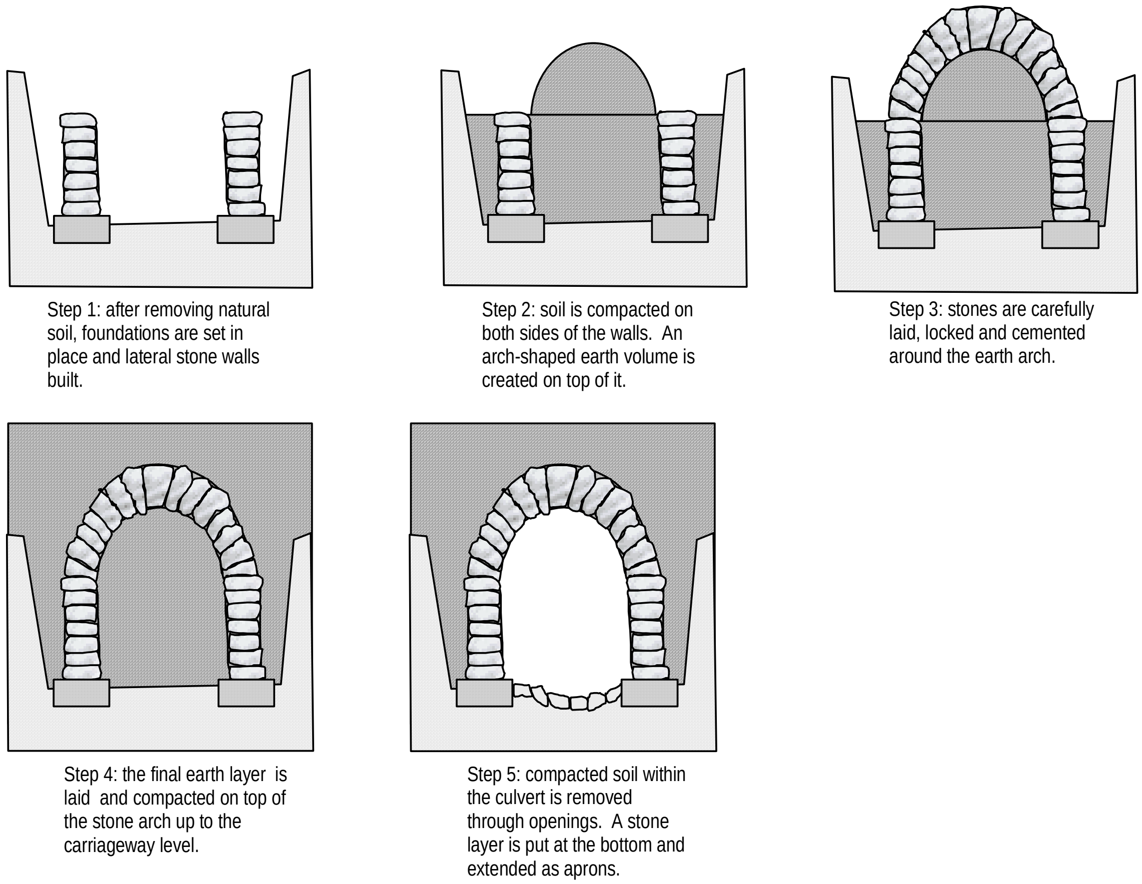
Multiple Culverts

The conventional solution to cross-drainage is the provision of culverts, usually made from prefabricated reinforced concrete or proprietary galvanized steel systems such as Armco. Large-diameter culverts are available that are capable of passing high discharges. However, such items are relatively expensive, difficult to handle without specialized equipment, and may require significant earthworks—out of proportion to the scale of work for basic access provision.

The alternative for basic access is the construction of unreinforced concrete pipes on site or the construction of small masonry arches. The minimum diameter should be 60 cm to ensure they can be cleaned. Such items can be installed in multiple lines to cope with larger flows.

Figure B.11 illustrates a labor-intensive procedure for the production of masonry arches.

Figure B.11. ***The Construction of Masonry Arch Culverts***



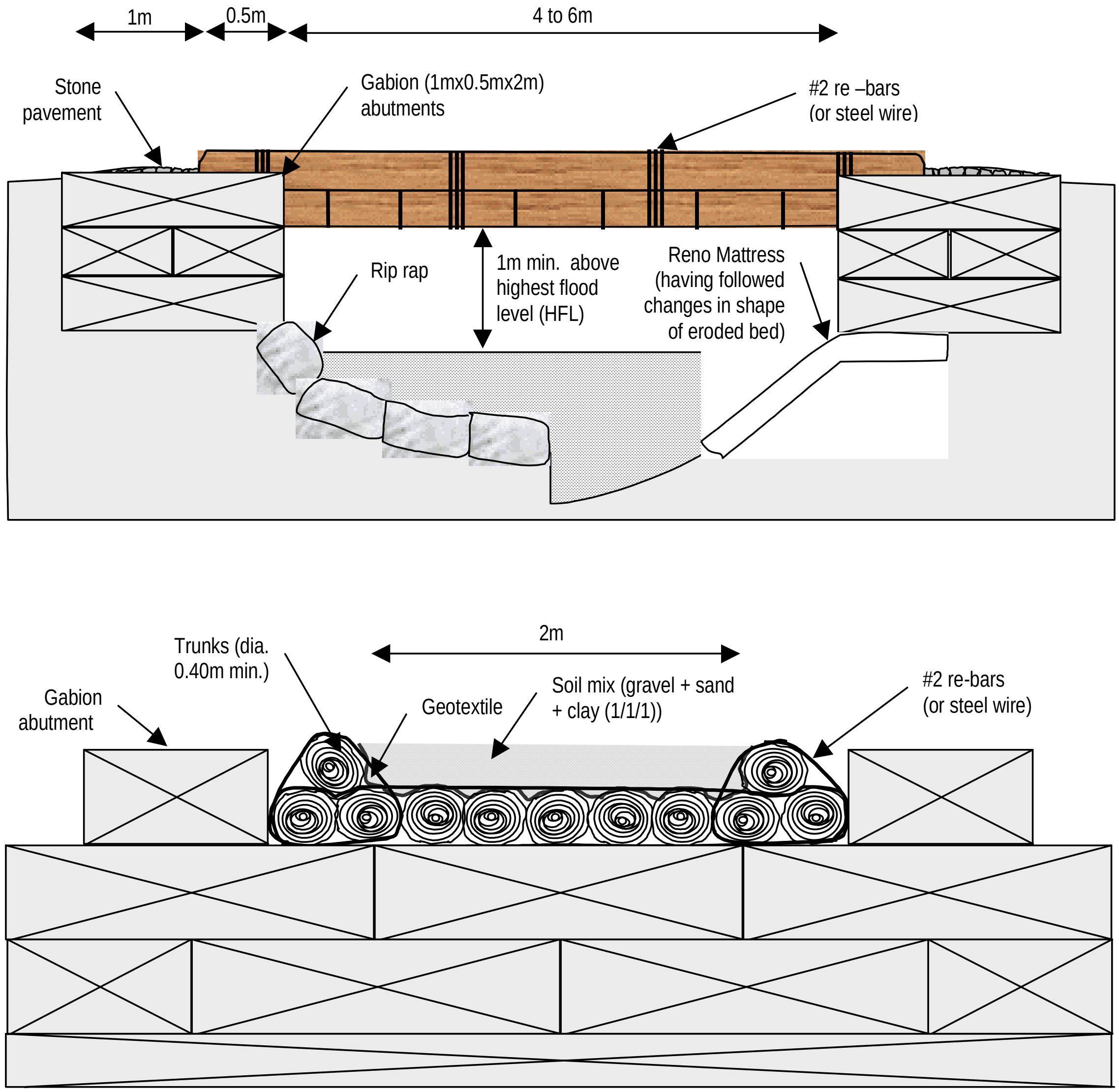
Source: Authors.

Bridges: Timber framework and masonry arch bridges provide a local solution that requires only limited equipment and local materials. Both masonry arch and timber framework bridges require artisan skills that are usually not available. In the context of large-scale labor-based bridge construction, it might prove cost-effective to build capacity by training local artisans.

The design life of timber varies from five years for untreated softwood to 20 years for hardwood timber. Treatment with chemical preservatives can extend the design life considerably. To be effective, treatment should take place in a pressuring device. An alternative is "hot and cold treatment" with creosote. Brush or spray treatments will provide only temporary protection.

Figure B.12 below, represents the most rudimentary wooden bridge, suitable for relatively low flows and light traffic. More sophisticated structures would involve piled abutments, sawn deck beams, and running boards.

Figure B.12. ***A Simple Gabion Abutted Log Bridge***



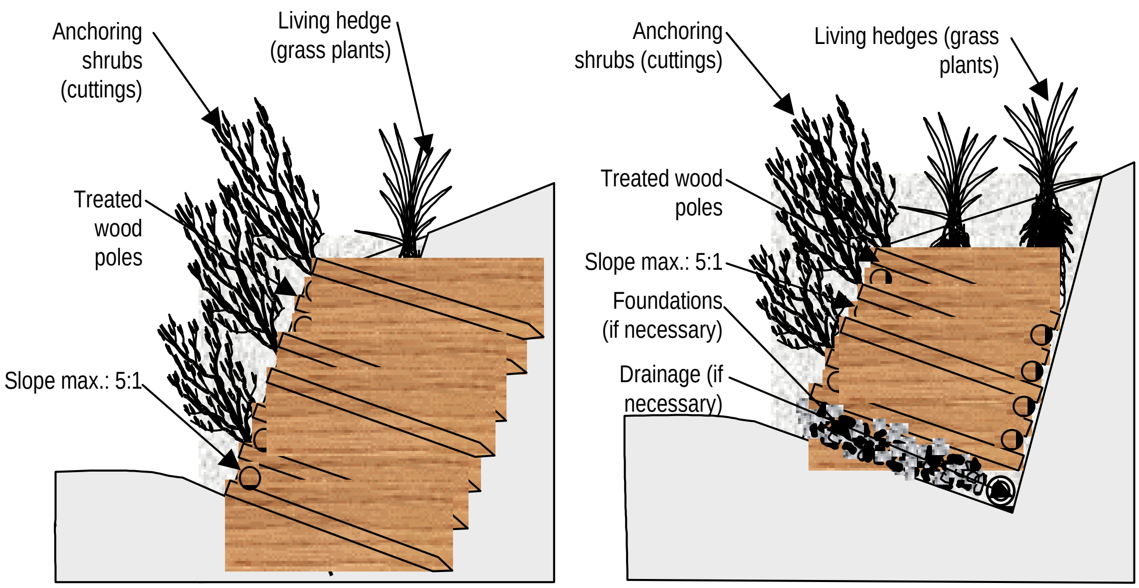
Source: Authors.

Bio-engineering

The major threat to the sustainability of low-cost earth and gravel roads is the erosive effect of water, in particular the scouring of side drains, drainage outfalls, road and embankment edges, and exposed slopes in cuts. Traditionally, it has been considered sufficient to rely on the eventual reestablishment of natural vegetation, or to encourage its growth by turfing. This rarely results in the best type of plant to resist erosion, however, with species that destroy carriageways and are not removed by maintenance workers. Alternatively, masonry and concrete check structures may be constructed—but these are expensive and often aggravate the situation.

Innovative work in several countries, but particularly Nepal[97] and the Caribbean islands, has demonstrated that it is possible to select and utilize particular combinations of plant species to provide sound engineering solutions. A common example is Vetiver grass,[98] which is used to stabilize terraces and gullies. Likewise, trees, shrubs, and other grasses may be used to stabilize slopes, protect embankments, and provide live check structures in drains.[99]

Figure B.13. ***Bio-engineering Retaining Walls***



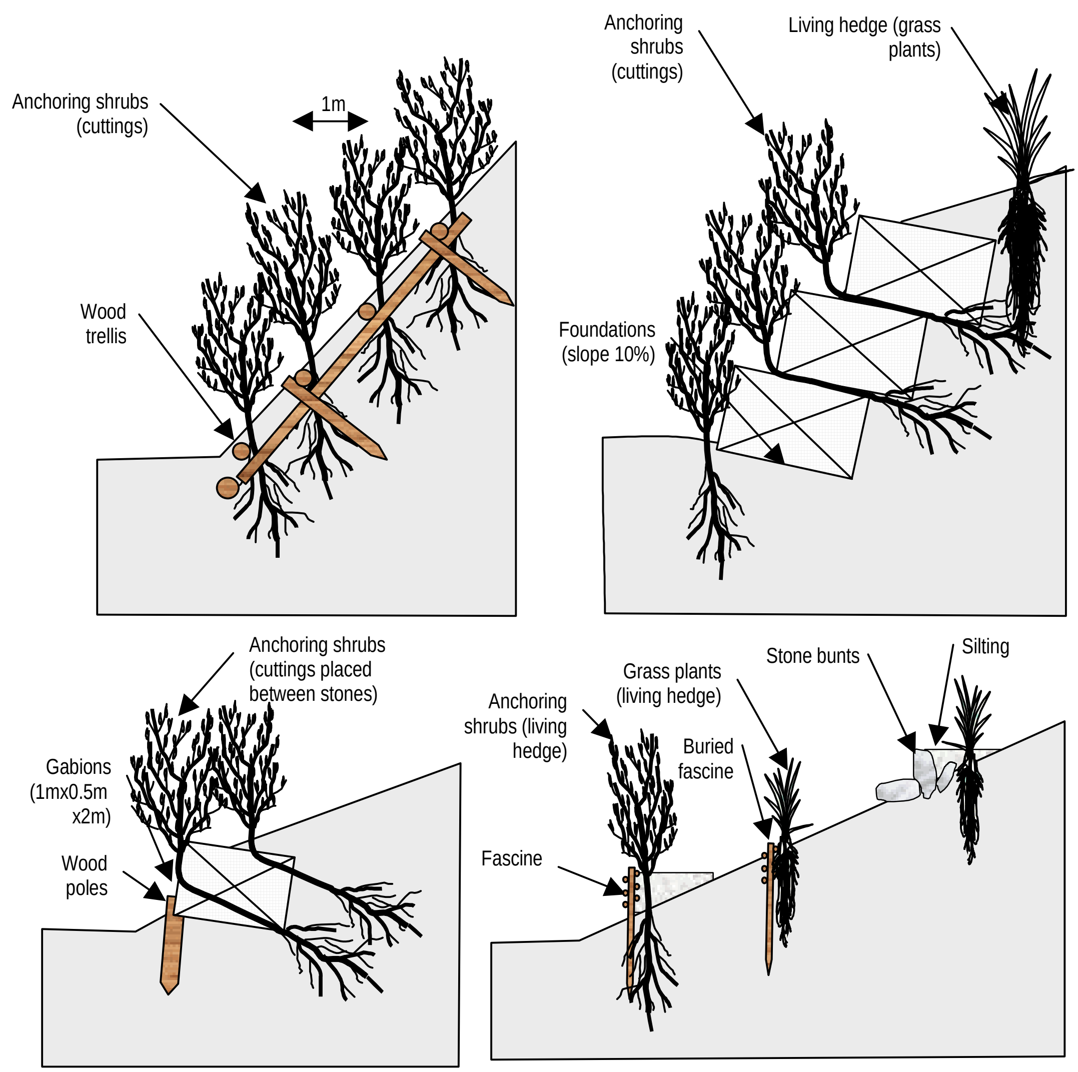
Source: Authors.

Suitable plant species can be grown in locally established nurseries. Works are very labor-intensive and require little capital investment. Skills developed may be useful in the community for other conservation projects. Some examples of the bio-engineered solutions to slope stability are given in Figures B.13 and B.14.

Wood "cages" are a temporary solution and their anti-erosion and anchoring functions will be performed by the plants as they become established. Dense grass hedges put on top of the "wall" anchor the top soil through their roots and reduce speed of run-off. Shrubs planted on the face provide deep anchorage.

The two solutions presented in Figure B.14 are aimed at stabilizing less-steep slopes with no imported fill. The solution presented on the left uses wood poles to build a mesh for plant cuttings. The wood trellis has only a medium-term operational life that the shrubs will replace. The solution on the right utilizes plants to complement the effect of the gabions.

Figure B.14. ***Bio-engineered Slope Protection***



Source: Authors.

The solutions above are aimed at controlling erosion on a moderate slope. The diagram on the left demonstrates the use of gabions that are durable. Cuttings are placed between the stones and complement stabilization in the long term. The diagram on the right presents three solutions for moderate slopes. The life of the fascines will be limited and plants are therefore the only long-term solution. Bushes or grasses can be used interchangeably as long as the density is high enough.

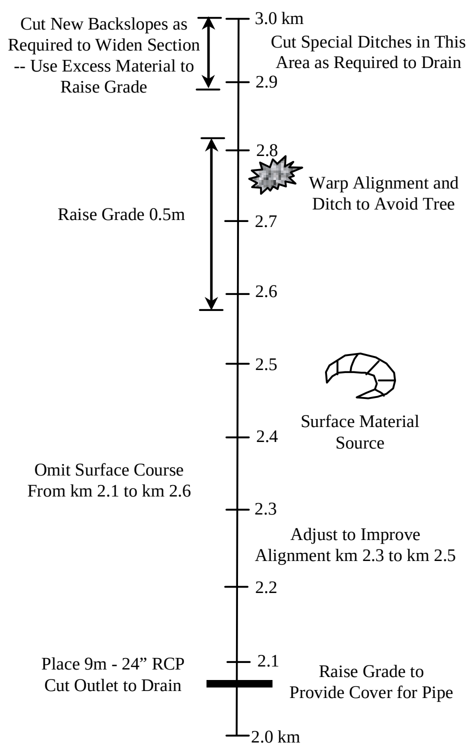
Appropriate Engineering Design of RTI

Often, the terms of reference (TOR) used as the basis for RTI designs are adapted from those used for the design of major highways. Such designs require a thorough survey with cross-sections at short intervals and vertical and horizontal alignments. However, such an approach is not justified for RTI if the costs are to remain within reasonable proportion of the planned investment (about 6 percent). The approach for RTI should be simpler and directed towards the production of line diagrams focusing on trouble spots for the solutions of which detailed designs need to be produced. Further details as to the design approach for RTI is discussed in Box B.3.

Box B.3. *Essential Requirements for RTI Engineering Services*

An Initial Road-Condition Survey

This survey should look at the existing level of access and determine the types of interventions necessary to secure the agreed basic access standard. Surveys should include a simple linear access plan indicating surface conditions, gradients, water crossings, and an outline of proposed remedial action. The survey should also include assessments of existing traffic, population densities, and prevailing economic activities. This survey will form the basis for initial project screening and prioritization. Depending on the program design, it may be necessary to carry out participatory planning exercises at this point to assess community interest and competence. This may be beyond the competence of the engineering consultants, but they should be involved in the exercise as resource persons.



Engineering Design of Spot Improvements

The linear plan should incorporate all proposed interventions, showing their location and the type of activity required. Details should be sufficient to allow a contractor to make a realistic estimate of costs, but is generally based on typical works rather than measured quantities. Typical work items will include:

- Clearing roadway of vegetation to stated width
- Reshaping existing roadway to provide camber
- Raising road grade to the specified level
- Providing side drains with scour checks as indicated
- Providing stone masonry or concrete drift
- Providing turnouts at stated intervals, and
- Providing gravel surface of 0.15cm compacted thickness.

Items should be summarized by linear quantity, and detailed with a simple specification.

Drawings and Bill of Quantities should be provided for more complex structures such as bridges, vented fords, and retaining walls.

Preparation of contract documents

The nature of these documents depend on the contract method adopted. For full competitive bidding where there is an active contracting sector, following the common procedures in the country or region is recommended. If these procedures are considered inappropriate for these types of small-scale works, then the FIDIC Short Form of Contract is recommended as a basis for the development of tailor-made documentation.

If non-competitive community contracting is used, the documents should be designed to ensure that the prices are adequate to cover the labor and material inputs required from the community, and to provide sufficient checks on progress and output.

Supervision and administration of the contract

For the level of works involved in basic access, a full-time consulting engineer as the employer's representative may not be justified. A trained "clerk of works" or the equivalent should ensure day-to-day quality with monthly visits by the engineer to monitor progress and certify payment.

However, if the services of the engineer are to include an element of training and development for the contractors, different arrangements will have to be put in place. This should not be considered as a cost to the road intervention but rather as an element of the overall program development process.

Source: H. Beenhakker et al, 1987, and authors.

Executing the Works

Rural transport infrastructure has traditionally been executed directly by a road agency or local government organization as a force account operation. Evidence in many countries has shown that this approach is ineffective and inefficient and one of the root causes for the poor state of many rural road networks.

The favored approach is to use existing commercial procedures, contracting out the work on a competitive basis wherever possible. However, it has to be recognized that commercialization of the road sector is in its infancy in many developing countries and the private sector is often inexperienced and poorly equipped for road work at the central level. The situation at the local level is generally much worse.

While this makes commercial implementation difficult, basic access interventions have the advantage that they are relatively simple and straightforward, and training local firms and organizations is therefore relatively easier. In addition, the use of labor-based methods ensures that equipment investment costs are low and more within the means of small contractors.

The basic requirements are: to identify potential contractors, including their needs and limitations; introduce appropriate contract procedures; develop training and support packages; and then implement the work in parallel with a capacity-building exercise for the client (in this case the identified owner of the infrastructure), and the local construction industry.

There is now considerable experience in this process and a number of alternative routes that can be followed. The recent ILO publication *Capacity Building for Contracting in the Construction Sector*[100] is primarily aimed at rural roads using labor-based methods and draws on worldwide examples over the past decade.

Contracts are not limited to commercial competitive bidding, but include the use of government contracting agencies, appointed agents that use a development team approach, large-scale contractors that manage small emerging firms as subcontractors, and community contracts with the benefiting communities.

An overview of alternative arrangements is shown in the Table B.2 below.[101] The choice is totally dependent on local experience and resources, but the long-term aim must be to develop procedures and practices that will be sustainable in the local economic and political framework once donor funding ceases. Future maintenance will be largely dependent on the success of this phase.

Table B.2. ***Alternative Arrangements for Executing Basic Access***

Production Arrangement	**Contracting**					
Approach	**Using Established**		**Developing Small-scale**			**Communities**
Delivery Mechanism	**Conventional**	**Sub-contract**	**Government-run**	**Agency**	**Development Team**	**Community Groups**
Diagram	Employer ↕ Established Contractor ⋮ Laborers	Employer ↕ Established Contractor ↕ **Small Contractor** ⋮ Laborers	Employer ↕ **Small Contractor** ⋮ Laborers	Employer ↕ AGETIP / Consulting Firm ◆ **Small Contractor** ⋮ Laborers	Employer ↕ **Small Contractor** ⋮ Laborers; Employer ↕ Consulting Firm and/or Established Contractor; **Small Contractor** — Consulting Firm and/or Established Contractor	Employer ↕ **Community Groups** ⋮ Laborers
Countries (examples)	South Africa Namibia	India Nepal Egypt South Africa	Benin Cambodia Ghana India Indonesia Kenya Lesotho Madagascar Namibia Nepal Sierra Leone South Africa Tanzania Uganda Zambia	**AGETIP:** Benin, Burkina Faso, Chad, The Gambia, Guinea-Bissau Madagascar, Namibia, Mali, Mauritania, Niger, Senegal Tanzania, **Consulting Firm:** Nepal South Africa	South Africa **Legend:** ↕ contractual relationships ⋮ employment relationships │ other relationships	Nepal Nicaragua South Africa Uganda

Source: Adapted from Stock and de Veen, 1996.

However, even the definition of small-scale contractor can be very flexible, as illustrated in the following examples from Ghana and Nicaragua.

Box B.4. ***Two Examples of Small Contracts***

Department of Feeder Roads, Ghana
More than a decade ago, the Highway Authority in Ghana decided to develop a new class of small contractor contractors. A typical contractor employs up to 200 workers using labor-based techniques, has approximately $150,000 worth of small equipment, and is capable of producing 30 km of engineered gravel road annually. Some 96 contractors have been trained to date. Contracts are awarded under specially adapted FIDIC conditions

Atlantic Coast Transport Program, Nicaragua
The Atlantic Coast Regions of Nicaragua are significantly underdeveloped compared to the rest of the country, with many isolated communities and difficult communications. DANIDA has been involved in a comprehensive program of assisting local municipalities and communities to rehabilitate and improve their transport network. Much of the work has focused on achieving basic access by improving tracks and footpaths.

Engineering design and supervision are the responsibility of the specially established program teams, but the work is carried out mainly by small labor-only community contracts. These contracts typically involve 25 workers who appoint a leader who signs the contract and organizes the group. The leader receives training from program staff.

Rates are decided by program staff based on daily output levels set by the workforces themselves. Since communities are inexperienced in this type of work, program staff should especially ensure that workers are adequately paid and properly equipped.

Source: Authors.

Maintenance of Basic Access Roads

Effective maintenance is the most important prerequisite for safeguarding the investment and ensuring that the road serves its purpose over the anticipated lifetime. A road should not be rehabilitated or constructed if maintenance cannot be afforded and managed. Low-volume roads in tropical and subtropical climates require careful and usually continuous maintenance throughout the year. Part of maintenance management is also effective traffic control to avoid unnecessary damage (excessive loading, traffic during heavy rains). For basic access roads, the following operations are necessary: routine maintenance, grading and periodic maintenance.

Routine Maintenance: Routine maintenance involves drainage opening and repair, carriageway repair, vegetation control, and erosion control on slopes. All of these operations are carried out using labor. All-year routine maintenance, basically on a daily basis, is required for roads in high rainfall areas, while roads that experience low rainfall require less attention during the dry season (Box B.5).

Box B.5. ***Labor-Based Routine Maintenance***

Labor-based methods are particularly suitable for routine maintenance of basic access roads. All activities can be carried out using labor only with the exception of grading and compaction, which are only necessary on higher traffic roads. There are basically four different labor-based contract types for routine maintenance:

- **Single-length person contract:** a contract for a defined section of a road (1 to 2 km) is given to an individual
- **Petty contract (or labor group):** a contract is given to a very small contractor who in turn employs a small team (5 to 10 laborers) to maintain a defined section of a road (5 to 20 km)
- **Small-scale contract for a particular road:** a contract is given to a small-scale contractor who employs laborers to maintain a particular road or a longer road section (20 to 100 km), and
- **Small-scale contract for a specified road network**: a contract is given to a small-scale contractor to maintain a specified road network, such as a full maintenance area covering all earth and gravel roads (100 to 300 km of roads).

The **length-person system**, whereby small and manageable tasks are allocated to individual workers (according to priorities throughout the seasons), is the cornerstone of all the approaches, and is therefore explained in more detail below.

System:
A laborer is appointed for each section of road, typically 1 to 2 km in length. A supervisor provides tools and monitors the condition of the road, directs operations, makes reports, and authorizes payments for satisfactory work. This person may be able to supervise up to 10 laborers or 20 km of roads. The laborer lives adjacent to the location of the maintenance activities and therefore does not require any transport. The task rate system is ideal for this sort of work.

The **advantage** of the length-person system is that a continuous maintenance of the entire road can be guaranteed at all times and that one person is responsible for a specific road section. This system is particularly useful in high rainfall areas where, for example, the opening of culverts and mitre drains needs to be carried out on the entire stretch of road almost on a daily basis.

The **disadvantage** is that supervision has to take place on each and every section of the road, which means that each laborer has to be individually instructed. The supervisor therefore must be very mobile and the laborers must be well-trained so that they can work independently. A large part of the time the supervisor is busy traveling from length-person to length-person. The length-person system can easily be transformed into a group system by pulling a number of laborers together and giving them a group task. This is of particular interest to contractors who would like to rationalize their supervision input.

Transport and Tools:
Transport is required for the supervisor (bicycle) and for the contractor (pick-up) to oversee all maintenance work and to transport tools and materials.

Each length-person requires a standard set of hand tools: hoe, shovel, grass-cutter, bush knife, and a rake or spreader.

Two or three length-persons may share: a wheelbarrow (to haul gravel from stockpiles or remove silt and organic material) and an earth rammer (for pothole filling). The gang leader requires a basic set of measuring aids: tape measure, ditch template, spirit level, strings, and pegs. In some projects it may also be necessary to provide the leader with a long-handled shovel and trowel to clean out culverts.

Source: Authors.

Grading: Grading is part of the routine maintenance procedure for unpaved roads. It is required to remove ruts and corrugations and generally reestablish the water-shedding qualities of the surface. The operation can require heavy machinery but, fortunately, this is not typically required for the lowest-volume roads. Labor equipped with handtools can achieve adequate results for low-speed basic access. However, where grading is unavoidable due to higher traffic volumes, one to two cycles may be required annually for low-volume roads. This operation can be carried out with a motor grader, but more appropriately with intermediate equipment, like a light tractor-towed grader (Box B.6).

Box B.6. ***Grading of Basic Access Roads***

For basic access road maintenance, mechanized grading is in most cases not necessary. Experience from various projects has shown that the carriageway of these roads can be maintained by labor alone. However, for roads with a traffic level close to 50 VPD and with a surface material that is relatively weak, grading is an option. For maintenance grading, intermediate equipment (tractor-towed graders) can achieve the desired results, and for lighter operations, a tire drag is often sufficient. For maintenance purposes, there are two types of grading operations:

Heavy grading:

- used when the surface has a severe amount of potholes and ruts. Done preferably at the beginning of the rainy season, and/or at the end of the wet season when the moisture content of the surfacing material is still enough to help re-compaction;
- scarifying and cutting to the bottom of the deformation;
- reshaping the surface;
- compacting loose material.

Light grading:

- used when the surface is corrugated and rough;
- light trimming of the surface;
- light compaction of the loose material would be advantageous, preferably during the wet season or when the surface material still has some moisture content to allow for compaction.

Surface material with a relatively high clay content can be more easily graded when still moist. Best practice experience suggests that grading frequency for roads with a traffic level of 50 VPD is two times per year, of which one grading should be heavy and one grading would be light. The costs for maintenance grading are in the range of $250 to 400 per km and cycle.

Source: Authors.

Periodic Maintenance: Periodic maintenance for gravel roads involves replacing the gravel-wearing course. This is also termed regravelling. Depending on the traffic level and the climate, a regravelling cycle of five to eight years is common (Box B.7). Usually not only does the gravel surface have to be renewed, but reshaping work of the formation, reinstatement of the drainage, and other repair work are required at the same time.

Box B.7. ***Gravel Loss***

Good surface maintenance is a prerequisite to safeguarding the gravel layer and to reducing maintenance expenditures. Maintenance engineers need to carefully assess the gravel surface condition on at least a yearly basis and monitor the gravel loss. The loss is never uniform along the entire road and partial regravelling is often the most cost-effective approach.

The rate of the gravel loss is mainly determined by the traffic, the gravel quality, and the prevailing climate. For example, with an average daily traffic of less than 50 VPD, the loss of lateritic gravel is in the range of 10 to 30 mm depending on the annual rainfall (1000 mm to 3000 mm, respectively).

As rule of thumb, a gravel layer needs to be replaced every five to eight years.

Source: Authors.

Regravelling is the most expensive maintenance operation for unpaved roads and over the lifetime of a road may cost the same, or even more than initial construction. The reality in most developing countries is that regravelling is rarely or never done when necessary. This is not entirely due to bad management and lack of funds. In some countries, suitable gravel is reported to be a rapidly diminishing resource. The result is that roads deteriorate until they are no longer maintainable and have to be reconstructed long before their planned design life expires.

Most basic access roads will not be fully gravelled. However, all those sections that are gravelled will still be subject to a wearing process and will need renewal at some stage. Rather than setting up a periodic program that may not be affordable by local government or the communities, an alternative is to integrate regravelling operations into routine maintenance. Spot regravelling can then be carried out annually as required. Gravel is stockpiled at key points and the entire operation can then be carried out labor-intensively by the routine maintenance contractors.

The Costs of Alternative RTI Road Improvements

Exact figures for the construction and maintenance costs of basic access roads cannot be provided (as prevailing conditions and input costs differ from country to country, and project to project). There can also be significant differences in the logistics of a project, especially the costs for hauling material, the availability of suitable tools and equipment, and the skills and experience of supervisors and workers. However, some guidance from best practice projects is useful for providing likely ranges. Box B.8 gives a general indication of the likely range of costs for spot improvement, construction, and maintenance of basic access roads in different circumstances. Before any conclusions can be drawn in a particular circumstance, detailed cost analysis of the possible alternatives should be carried out. Such analysis should always investigate total life-cycle-cost (construction and maintenance).

Box B.8. ***Estimated Costs for Spot Improvement, New Construction, and Maintenance of Basic Access Roads (all single-lane roads)***

Spot improvement to existing motorable track	
In rolling and flat terrain and low rainfall	$1,500 to 2,500/km
In mountainous and high-rainfall area	$5,000 to 20,000/km
Construction	
Earth-road construction in mountainous areas	$10,000 to 50,000/km
Earth-road construction in hilly and flat areas, no embankment required	$6,000 to 15,000/km
Earth-road construction in flat areas, embankment required	$8,000 to 30,000/km
Gravel surface, 12 to 15 cm compacted, 3.5 to 4.5 m wide, hauling distance between 2 and 8 km	$5,000 to 8,000/km
Stone pavement, 20 to 30 cm strong, sealed, three to four m wide	$10,000 to 15,000/km
Surface dressing, (single seal, double seal)	$2 to 3 per square meter
Clay or concrete brick paving (or 5cm asphalt concrete layer)	$8 to 10 per square meter
Maintenance	
Routine maintenance of gravel road (by labor)	$200 to 600 km/year
Grading of gravel road (by equipment: average of light and heavy)	$250 to 400 km/cycle
Periodic maintenance (regravelling every five to eight years)	$5,000 to 8,000/km

Note: Construction costs include all construction work (contracted out) plus design and contract supervision, but do not include agency costs. The costs include an average number of small structures (for example, drifts, multiple culverts) and water crossings (splashes, small drifts, or culverts), but not bridges.

Source: Authors.