Chapter 22*

PREFEASIBILITY ASSESSMENTS OF MOUNTAIN ROADS

22.1 MINOR ROADS

The alignment of minor roads is normally a question of a single alternative, since the choice of route for these roads is dictated by popular will and existing trails rather than techno-economic analysis. Thus, there is generally no comparison of alternatives involved.

Prefeasibility assessments of such roads are limited to rapid assessments of lengths, standards, costs, and benefits.

22.1.1 *Preliminary Survey of Road Alignment*

Local level technicians, along with local representatives, should identify nodal points, carry out walk-over surveys, and review and determine the final nodal point. Location surveys should be carried out with the help of measuring tapes, ranging rods, and Abney levels. Landslide areas, erosion prone areas, rock cliff areas, gradients, switchbacks, number of crossings, and drainage works should be identified and recorded. The alignment is then finalized by avoiding hazardous areas as much as possible. Based on the above information, the geometric standards and construction techniques should be established so that hazardous areas are least disturbed, and so that cost is kept to a minimum by using labour intensive techniques and local materials to the maximum extent.

22.1.2 *Assessment of Quantities and Cost*

Quantities of various items of roadwork may be calculated on the basis of similar existing roads, using typical cross-sections for the representative sections. Costing should be done on the basis of historical cost data for similar situations and on the basis of rate analysis for the respective items. Per kilometre quantities and costs from similar existing projects, if available, may be used to compare the calculated costs. Tables should be used, whenever applicable, for determining the standards, cross-section, and tentative quantities.

22.1.3 *Socioeconomic Assessments*

For minor roads, the assessment of socioeconomic importance, either for the purpose of making a decision on whether to take up the project or not, or for comparison of alternatives, if any, should be based on a generalised heuristic method, given as follows (Table 22.1).

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* Tables and Figures without credit lines in this Chapter are compiled by the author.

Table 22.1 Rating scheme for rural access roads

Criterion	Factor	Measurement unit	Measuring parameters	
			Range of factor values [1]	Rating scale [2]
Economic activity	1. Net increase [3] in agricultural production in 5th year of project inception per km	Tons of agricultural production in 5th year of project inception per km	0-10,000 tons	0-100
	2. Net increase in livestock production in 5th year, per km	Head of cattle	0-5,000	0-100
	3. Traffic Volume	ADT	0-100 veh/day	0-100
	4. Cost per km	U.S. dollars equivalent	$5,000 - $30,000	0-100
Social service	5. Population served per km	No. of persons/km	0-1,000 persons	0-100
	6. Improved access to education and welfare	Presence of such facilities in area of influence of road	Yes No	1,000
	7. Improved access to administrative and market centres	Additional number brought within the 12hr travel time zone centre, per km of road	0-500 persons	0-100
Social and economic	8. Employment generation	No of jobs created/km	0-2,000 man-days	0-100
	9. Income distribution	Use of labour-intensive technology	Yes No	1,000
	10. Distribution	Percentage of small farms [4] within area of influence of road	0.100%	0-100

Source: Adapted from Carnemanrk et al., 1976 (World Bank Staff Working Paper No. 241).

Notes on Table 22.1

1/ The range of the factor values is defined by the limits for the factor obtained, or estimated for the proposed set of roads. These limits should be stated in round numbers.

2/ The common rating scale 0 - 100 corresponds to the range of values obtained or estimated for the various factors.

3/ Estimated net increase with the road compared to the without the road condition. A five year lap period is allowed to develop full agricultural potential. The total net increase in production is divided by the length of road to ensure uniform and compatible units for the purpose of comparison.

4/ Small farms are defined as individual holdings under 2 hectares.

5/ The criteria and factors involved indicate the objectives that should be sought, but the detailed criteria and factors involved will depend upon the particular objectives of individual countries, or regions within a country. The factors used, and the units in which these are measured, must be related to the available data or the ease with which data can be collected, otherwise the cost can be prohibitive.

6/ The relative weights given to each criterion and sub-criterion or factor, recommended by the World Bank, are in Table 22.2. They can, of course, be altered to suit individual government objectives.

7/ The rating may be adjusted according to the conditions specific to the user agency.

8/ There may be a great deal of double-counting, e.g., among factors 4, 8,9, and 10.

Table 22.2 Relative weights for criteria and factors

Criterion (Weight)	Factor	Factor Weight (%)
Economic Activity (50)	1 2 3 4	10 5 10 25
Social Service (25)	5 6 7	15 5 5
Social and Economic welfare (25)	8 9 10	10 5 10
Total	7	100

Source: Carnemanrk et al. 1976

22.2 MEDIUM ROADS

22.2.1 *Background and Summary*

The prefeasibility assessments of these roads are more involved and include identification of various alternatives, their comparisons, and rankings so that choices are reduced to one or two alternatives for the feasibility stage assessments. Nodal points/obligatory points should be ascertained first.

Various alternatives need to be identified using topographical maps, air photos, and walk-over surveys. Each alternative should then be evaluated in terms of hazards and risks, traffic levels, standards, technology, environmental impacts and economic viability, construction time, initial investments, and strategic considerations.

Table 22.3 presents a summary of activities for prefeasibility assessments. Problems and guidelines for various aspects of prefeasibility assessments are presented below.

22.2.2 *Staging*

Stage construction consists of planned improvements to the road standards at fixed stages throughout the project life. Stage construction differs conceptually from upgrading in that any later improvements are planned from the outset. On the other hand, upgrading projects aim specifically at providing additional capacity when a road is nearing the end of its design life or when there has been an unforeseen change in the use of road.

Table 22.3 Checklist of activities at the prefeasibility stage for medium roads

	Activities	Basis/responsibilities
1.	Ascertain functional classification	Road network plan and policy decisions
2.	Determine tentative traffic levels and standards	From past experience
3.	Collect data on quantities and cost from similar roads.	Literature search and historical records
4.	Collect topographical maps, air photos, land use maps, geologic maps.	Existing sources (government agencies, consultants, and international agencies)
5.	Collect data on socioeconomic aspects from available reports.	Existing sources (government agencies, consultants, and international agencies)
6.	Develop alternative alignment using existing topographical maps and air photos.	Office work by location engineers, engineering-geologists
7.	Assess hazards and risks by desk study of existing topographical maps as photos, and geological map survey.	Field visit by a team of surveyors, engineering-geologists, geotechnical engineer, highway engineer, economists, environmentalists.
8.	Conduct walk-over survey, review alignments using altimeter, Abney level, and compass; collect data on hazards, risks, traffic, socioeconomic aspects, and environmental aspects (Initial Environmental Examination,IEE).	Desk work by engineering geologists and engineers.
9.	Assess hazards.	Engineering-geologist civil engineer.
10.	Assess Initial Environmental Examination.	Environmentalist.
11.	Decide on geometric standards and typical cross-section designs.	Based on hazard levels, terrain, traffic levels, risk and cost minimization principles, adverse environmental impact minimization principles.
12.	Carry out rate analysis for new and important items.	Desk work by engineers and estimators.
13.	Assess risks.	Civil Engineer, Engg-geologist.
14.	Determine quantities and cost for construction and maintenance.	Typical cross sections
15.	Carry out socio-economic analysis.	Cash flow analysis by transport economists.
16.	Carry out final analysis of initial environmental examination (IEE).	Environmentalist, hill road engineer, and engineering geologists.
17.	Develop selection criteria for comparison and ranking of alternatives.	Existing plans, policies, and directions by policy level engineers.
18.	Summary of findings.	Draft final report to be reviewed and verified by a repeat walk-over survey.
19.	Weighting and ranking of alternatives and final report.	Final report to be approved by competent authority.

The following are problems related to the staging of hill roads:

- o any change in gradient requires a change in alignment,
- o extension of pipe culverts for additional road width requires the dismantling of existing pipes and catchpits,
- o existing side drains are destroyed during road widening,
- o hillside walls (breast walls, etc.) are destroyed during road widening,
- o slope stabilization works are destroyed during road widening,
- o new cutting destabilizes the already stabilized uphill slopes,
- o side-casting destabilizes the downhill slope,
- o widening at stacks of switchbacks is almost impossible,
- o erosion of road bed and downhill slope is considerably enhanced by unsealed road surface, and
- o unpaved roads in the hills need to be restricted to not more than six per cent longitudinal gradients to allow truck movements during the rainy season and to minimize erosion.

Hill roads, therefore, do not lend to staged construction but, should staging become unavoidable because of low-cost considerations or other socioeconomic constraints, the following practice is recommended:

- o alignment selection based on location survey and hazard assessment by location engineer and relevant engineering-geological expert,
- o longitudinal gradient in unpaved areas not to exceed 6 per cent,
- o paving and surface sealing in critical sections such as steep gradients and wet areas,
- o outsloping the road wherever possible,
- o use of dry masonry and gabions for retaining walls,
- o use of causeways for cross drainages, and
- o design pipe culverts and slab culverts so that future extension is possible without complete removal of existing structures.

22.2.3 *Hazards and Risks*

(a) *Background*

Assessment of hazards and risks in a round alignment involves assessment of i) state of nature, (ii) dangers, (iii) hazards, and (iv) risks.

State of Nature

Basic information describing the state of nature is collected from existing maps such as air photos, topographical maps, geological maps, land use maps, seismic maps and rainfall data maps, and the field survey and mapping.

Dangers

Information on existing landslides, gullying, undercutting, debris flows and mudflows are collected from the field survey. The type and size of instabilities and their effects are also recorded wherever possible. Information on danger events such as glacial lake outburst floods (GLOF), landslide damming, and river undercutting are also collected.

times worth of loss. The length of road likely to be affected by hazard and the per cent of road loss due to the type of likely failure determines the worth of loss. This can also be expressed in monetory value.

The assessment of hazards and risks can be done either by the use of tabulated data or by the preparation of maps.

For prefeasibility purposes, the use of tabulated data and use of calculations in standard formats are recommended since the amount of time and work for large-scale mapping for all alternatives would be enormous. Small-scale maps can, however, be prepared easily at this stage also by using the existing maps and their tracings and recording field information on these maps.

Tables 22.4, 22.5, 22.6, and 22.7 are suggested for data records which should first be collected during desk studies and then finalized after the field survey. The ratings for various factors in these tables are obtained from the predetermined rating charts (Tables 22.8,22.9, 22.10, and 22.11). The total rating for the state of nature of a given road section is multiplied by the rating for rainfall to obtain the hazard rating for the state of nature (Table 22.4).

The type of probable failure (shallow landslide or deep-seated landslide) is indicated below the rating based on the depth of soil and the failures in the nearby areas.

Hazard is assessed for the dangers along the road length within each facet as below:

hazard for road length affected by danger - hazard for the state of nature + (1- hazard for state of nature) x rating for rainfall.

This assumes that :

i) the hazard for state of nature is increased by the existing danger, the total hazard being net greater than 1.0, and

ii) the road is so designed that there is no significant modification to hazard.

Assessing hazards and risks for the entire design life is complicated. It is therefore suggested that hazards and risks be calculated for high frequency and that risks be calculated for high frequency and low frequency separately. For most purposes, at the prefeasibility stage, the first time hazard and risk likely to occur immediately after road contruction is adequate, and, therefore, only five-year return-period rainfall intensities are considered. Nevertheless, low frequency hazards and risks, i.e., the hazards and risks likely to occur because of major events such as 10 or 20 year return period rainfall, can be calculated, if desired, by using the rainfall factors corresponding to the return period desired.

Data, if available, on glacier lakes, landslide dams, lake outburst floods, and effect of cloudbursts should be collected to assess the major dangers likely to be caused by them during the design life of the road. Table 22.6 is suggested for the calculation of risks due to state of nature and dangers.

Risk calculation requires the use of a factor for obtaining the per cent of road likely to be damaged by the type of landslide. Shallow or minor slides do not completely damage the road. Table 22.11 gives damage factors in soils and rocks for each type of failure. Here also, it is assumed that the road design adopted is based on hazards and that no significant modification of the hazard occurs by the technology adopted is based on hazards and that no significant modification of the hazard occurs by the technology applied to roads.

(b) *Activities during Prefeasibility Stage Hazard and Risk Assessments*

Desk Study: The following desk activities are undertaken during the prefeasibility stage.

Discussion: The assessment team should consult and discuss with project engineers on alignments and nodal points/obligatory points, and in other issues pertaining to the study of the proposed road.

Data collection: The following state of nature data should be aquired:

- o topographic maps of 1:50,000 scale,
- o information on past construction activities in similar terrain,
- o metereological records,
- o hydrological/hydrogeological records,
- o land use, land system, and land capability maps,
- o soil maps,
- o landslide susceptibility maps, state of nature maps, hazard and risk maps,
- o landslide susceptibility maps, state of nature maps, hazard and risk maps, and
- o aerial photos and satellite imaging.

Preliminary Hazard and Risk Assessments

Assessment of hazards is based on the study of the state of nature (i.e., rock, soil, geomophology, and the like), danger and trigger types (i.e., landslides, GLOF, debris/mudflow seismicity, etc), and prior frequency of occurrence of damaging phenomena. Hazard and risk are dealt with in detail in Chapter 14. Using the information and records mentioned above, a preliminary hazard and risk assessment should be made along the alternative routes. For this purpose the following state of nature maps are prepared in the office and verified by the walk-over survey.

Topographic map

The 1:50,000 scale topographic map with contours region between two endpoints should be reproduced together with the alternative routes. On the same map should also be shown major landslides and other types of danger as well as the observation points.

For this purpose, the air photos are studied under the stereoscope. They provide with a three-dimensional view of the entire region. As computer technology becomes accessible the satellite dates may be quite useful for this purpose. The air photos are useful in the study of land forms (i.e., the rock soil types, geological structures, folds, faults, joints and crushed zones, drainage patterns, landslides, and land use. The air photo interpretation techniques are discussed in Chapter 8. The above features should be plotted on the map as far as practicable. The topographic maps also provide the information on drainage patterns, old river courses, past landslides, steep rocky areas, and escarpments.

Slope Map

The topography of the study area is divided into various facets (slope faces) delimited by the ridges, spurs, and gullies/rivers. The air photos should be studied for more accurate limits of each slope face. The slope angle for every slope face is calculated from the contour density on the topographic map. If there is a remarkable variation within a slope face, it should be further divided into smaller uniform units.

Geological Map

The geological information should be plotted on the 1:50,000 scale topographic map along a route strip of about 3 km width on both sides. Alternatively, the routes should be transferred on to the existing 1:50,000 scale geological maps. The geological maps provide the information on lithology (rock type), folds, faults, bedding/foliation, joints, and potential construction material.

Data Collection for Hazard and Risk Assessments

Tables 22.4 to 22.11 are designed for data collection. The attributes included on the tables are described below.

The alternative routes are divided into various segments depending on the slope face and other considerations. And, for each segment, that state of nature and types of danger are identified.

Section type refers to the ridge, valley (flat or gorge) or climb sections. There is no rating assigned for it, as it is considered in the slope and relative relief attributes.

Slope angle is directly read out from the slope map. Table 22.24 summarises the ratings for each attribute, which could be modified if necessary.

Relative relief is the relative height between the closest, gentler slopes up and down the route.

Drainage density is estimated from the air photos and topographic maps. The first, second, and higher order streams should also be identified.

Groundwater Conditions should be obtained from the air photos and field observations of seepage points, local pools of water and existing wells, if any.

Rock and soil types, rock structure, land use, and types of danger are also obtained from the maps, records, and fold observations.

Walk-over survey

The alternative routes chosen during the desk study should be confirmed in the field. The field walk-over survey should preferably be performed by a team consisting of the road location engineer and the engineering geologists. The information on rock/soil type: assumed soil depth, slope angle changes, river undercutting past, present, and dormant landslides (see Table 22.9) should be carefully studied or rechecked and the topographic, slope, and geological maps should be corrected as far as possible.

Table 22.4 Hazard assessment data sheet for state of nature

Facet No. / Chainage / Attribute	Description	Rating	Description	Rating	Description	Rating	
A. STATE OF NATURE							
1. Section type							
2. Slope angle							
3. Relative relief							
4. Drainage density							
5. Groundwater							
6. Land use							
7. Major fault							
8. Major anticlinical							
9. Major synclinical							
10. Rock type							
11. Weathering grade and thickness							
12. Orientation of fractures							
13. Joint spacing							
14. Soil type							
15. Soil depth							
TOTAL RATING FOR STATE OF NATURE							
B. TRIGGERS							
16. Rainfall and annual mean annual max 24 hr.							
RATING FOR RAINFALL f_r							
C. HAZARD = A x B (High frequency)							
D. LIKELY LANDSLIDE							

Note: Use Table 22.8 for rating for state of nature, Table 22.10 for rating for rainfall determine type of likely failure (shallow slide, deep slide), by judgement based on observation of the existing failures nearby, based on danger data as per Tables 22.5 and 22.9, and by the soil depth in attribute No. 14 in Table 22.8.

Measures for erosion control and stabilization of minor slides should be incorporated on the basis of hazards. Figures and Tables may be used for guidance.

Table 22.5 Hazard assessment data sheet for dangers

Location of Danger		Danger Type	Danger Size	Hazard Rating for State of Nature P_s	Rating for Rainfall f_r	Hazard $Pd = P_s + (1-P_s) \times f_r$ $= (5) + [1-(5)] \times (6)$
Chainage	Length					
(1)	(2)	(3)	(4)	(5)	(6)	(7)

Table: 22.6 Risk assessments for high frequency failures

			Dangers				State of Nature			Total Risk, R (7) + (10)
Facet No.	Chainage	Length of Facet l	Hazard P_a	Type of Failure	Length of Road Affected l_r	Risk $= P_a \times l_r \times f_d$	Hazard P_s	Type of failure	Risk $= P_s (l - l_r) \times f_d$	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)

Notes on Table 22.6:

Road damage factor is different for the types of likely failures. Appropriate factor for the likely failure should be obtained from Table 22.11 and for the type of danger and for the type of failure for state of nature as indicated by Tables 22.4 and 22.5.

Table: 22.7 Hazard and risk assessment for low frequency dangers

Trigger Type	Danger Location	Probability of occurrence at least once in 20 yrs., p	Road Section Likely to be Effected		Risk p x l
			Chainage	Length l	
GLOF					
Landslide dam outbursts					
Cloudburst					
Earthquake Richter magnitudes* > 80 = 1.0; 70-79 = 0.8; 60-69 = 0.6; 50-59 = 0.4; < 50 = 0.2					

* An appropriate seismicity map for the region under study has to be consulted.

Table 22.8 Rating for state of nature

S.No.	Attribute	Description	Subdivision	Rating	Assumed Distribution
1.	Slope Angle	Very gentle Gentle Moderately gentle Moderately steep Steep Escarpment/cliff	0 - 5° 6° - 15° 16° - 25° 26° - 35° > 45°	0.0 0.05 0.10 0.18 0.14 0.10	
2.	Relative Relief	Very low Low Medium High Very high	0 - 50 m 51 - 100 m 101 - 150 m 150 - 200 m > 200	0.00 0.03 0.06 0.09 0.12	
3.	Drainage Density	Mainly first order gullies Second, third order gullies More than third order gullies	Simple Moderately dissected Highly dissected	0.00 0.04 0.06	
4.	Groundwater Conditions	Dry Wet Flowing		0.0 0.07 0.09	
5.	Land Use	Thickly vegetated Moderately vegetated Sparsely vegetated Barren land, dry cultivated land		0.00 0.01 0.04 0.08	
6.	Major Fault	Up to 50 m on both sides Onwards for 50 m Further onwards for 100 m		0.10 0.05 0.2	
7.	Major Anticlinal Core	Up to 50 m on both sides Onwards for 50 m Further onwards for 100 m		0.07 0.05 0.02	
8.	Major Synclinal Core (when the hinge is 1) Coming Out of the Slope	Up to 50 m on both sides Onwards for 50 m Further onwards for 100m		0.03 0.02 0.01	

Table 22.8 (Contd.)

S. No.	Attribute	Description	Subdivision	Rating	
9.	Rock type	Massive, resistant	Limestone Dolomite Quartzite	0.00	
		Soft rock	Shale Mudstone Phyllite, Schists	0.04	
		Alternating interbedding of soft and resistant rock	Phyllite + Quartzite Schist + Gneiss etc.	0.05	
		Weak rock in general	Crushed rock	0.06	
10.	Rock weathering grade	Fresh, slightly weathered Moderately weathered Highly weathered Completely weathered		0.00 0.03 0.04 0.03	
11.	Rock Structure: Joint spacing	Wide Medium Close Very close	> 1m 1m - 0.5 m 0.5 - 0.1 m < 0.1 m	0.00 0.03 0.04 0.06	
12.	Rock Structure: Orientation of discontinuities	Slope oblique to joint bedding for more than 35° Dip slope of joint (± 20°) Dip slope of bedding/foliation (± 20°)		0.05 0.16 0.10	
13.	Soil type	Compacted alluvial terrace Residual soil (eluvium) Colluvium Talus deposit Loose alluvium or loose all. terrace Moraine, diamicton, loose debris		0 - 0.04 0.04 - 0.06 0.06 - 0.08 0.08 - 0.10 0.10 - 0.12 0.12 - 0.18	
14.	Soil depth	Very shallow Shallow Deep Very deep	See rock rating 0-1m 1-3m 3-10m >10m	0.00 0.08 0.18* 0.16*	

Source: Dhital 1991

* for coarse and very coarse material rating = 0.06

Table 22.9 Check list of dangers

Rating for Dangers

S. No.	Attribute	Description	Subdivision
1	Old Landslides	Small Medium Large	Slope length above and below the road line: Less than 10 m 10 to 50 m > 50 m
2	Recent Landslides	Small Medium Large	Slope length above and below the road line: Less than 10 m 10 to 50 m > 50 m
3	Dormant Slides or Falls	Small Medium Large	Slope length above and below the road line: Less than 10 m 10 to 50 m > 50 m
4	Landslides due to river bank undercutting, wash out	Small	Height > 100m from road line to river bed* Height > 50-100m from road line to river bed* Height < 50m from road line to river bed*
			Depth less then 0.5 m Depth 0.5 - 2m Depth > 5m

Definitions:

Old landslide = stabilized landslide without destabilization features such as cracks or tilted trees, etc.
Recent landslide = landslide having very recently occurred
Dormant landslide = old landslide showing destabilization in process (recent cracks, tilted trees, etc.)

* As far as soil or very weak rocks are considered, for medium-strong and strong rock the height has to be decreased accordingly.

Table 22. 10 Rainfall factor for assessment of hazards due to rainfall

Average Annual Rainfall, mm (A)	Mean Annual Maximum 24 hr. rainfall, mm (B)	Rating f_r
	< 50	0.3
1000	50 -100	0.5
	101 -140	0.8
	141 -170	1.0
	170	1.0
2000	< 80	0.4
	81 - 120	0.6
	121 - 140	0.8
	141 - 170	1.0
	170	1.0
3000		
	< 130	0.5
	131-150	0.8
	151-121	1.0
	190	1.0
4000	< 160	0.6
	161-190	0.9
	191-260	1.0
	260	1.0
		1.0

Note: Use value of A in combination with Column B give the highest factor (f_r)

The factor weights (f) are assigned based on subjective judgement and should be adjusted wherever more information and statistics are available.

Table: 22.11 Factors for road damage, f_d (fraction of road length)

	Soil	Rock	Soil+Rock	Remark
Minor Slide (1-3m)	0.20	0.3	-	The percentage of damages is based on subjective assessment and can be modified for specific situations dictated by experience.
Medium Slide (3-6m)	0.5	0.6	-	
Major Slide (6m)	0.9	1.0	-	
Minor Debris Flow	-	-	0.20	
Medium Debris Flow	-	-	0.40	
Major Debris Flow	-	-	0.90	
Minor U.C.	0.3	0.10	-	
Med. U.C.	0.5	0.20	-	
Med. U.C	0.9	0.50	-	

22.2.4 *Traffic Levels*

Traffic Levels should be assessed on the basis of representative traffic counts and the traffic generated because of increased agricultural production as a result of road establishment.

22.2.5 *Geometric Standards*

Geometric standards should be determined on the basis of traffic levels, terrain, and hazard levels. The standard of roads depends primarily on design speed which is the maximum safe speed that can be maintained over a specified section of road. The basis of design, generally, is to select as high a design speed as possible to attain a desired degree of safety, mobility, and efficiency while considering the constraints of environmental quality, economics, aesthetics, and social or political impacts.

The problems with geometric design of hill roads are:

- o several valleys and ridges need to be traversed between two ends of a road,
- o single-lane roads require twice the sight distance required for double-lane roads because of vehicle conflict, and
- o in order for the sight distance to be effective, single-lane roads require offsets much greater than those of double-lane roads.

Table 22.12 indicates the vehicle weight to horsepower ratio for trucks common in Nepal. Table 22.13 provides indicative quantities of major items for hill roads for height of cut limited to less than 12 metres and for low risk design of cross-sections. Table 22. 14 provides suggested geometric standards for hill roads and Table 22.15 also provides guidelines for preliminary design of cut slopes. The table is mainly meant for trucks with a vehicle weight ratio of 200 to 300 lb/hp. The following are examples of vehicle weight ratio.

Table 22.12 Vehicle weight/horsepower ratio for trucks common in Nepal

Vehicle Type	Gross Vehicle Weight	Horse Power hp	Weight/ Horse Power, lbs/hp
TATA Trucks	12 to 13 MT	120 to 110	220 to 260
Japanese Trucks	12 to 13 MT	160 to 140	165 to 204
Cars		60 to 70	47 to 73

22.2.6 *Design and Costing*

The estimation of quantities of roadwork at the prefeasibility stage assessments has to be based on a rapid method and at the same time be within an accuracy of ± 25 per cent.

A lower risk approach for medium roads should, on the basis of desk work and walk-over surveys, include the following assessments.

a. Division of road into sections of various hazard levels using existing topograhical maps, air photos, and the information from hazard assessments.

b. Division of the lengths under each hazard level into various slope ranges based on topographical maps and walk-over reviews.

c. Determining road lengths under each slope category for each hazard level.

d. Determining road width and cut slope angle and cut and fill ratio for each road length under each slope category. Since full bench-cutting or cut-fill balance is most economical, the cross-section should be designed accordingly so that the height of the cutting is limited to 12 metres. Higher heights of cut in soil areas increase the hazard for medium hazard and high hazard areas; the height of cut should be limited to 10 m and 8 m respectively by providing breast walls and retaining walls. Tables 22.13 and 22.15 provide guidelines for preliminary design of cut slopes. Tables 22.16 to 22.18 provide guidelines on preliminary selection of retaining walls and breast walls.

e. Calculate quantities of cut, fill, retaining wall, breast wall, and culverts based on typical cross-sections from (a) above or (b) using Table 22.13. Formats for quantity estimation should be as per Tables 22.11 to 22.30. The estimated quantitites should be verified with the quantitites for existing roads.

Table 22.13 Indicative quantities of major items of hill road for height of cut limited to less than 12 metres and low risk design of cross-sections

HILL SLOPE deg.	AV. SLOPE deg.	CUT SLOPE deg.	H:V	ROAD WIDTH m.	RATIO CUT	FILL	CUT HT. m.	FILL HT.	HT.OF RTG. WALL m.	PER KM. QUANTITIES CUT VOL. 1000 cu.m.	FILL VOL. 1000 cu.m.	RETG. WALL VOLUME 1000 cu.m.	BREAST WALL VOLUME 1000 cu.m.	CULVERT No./Type	REMARK
LOW HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP + 2/Box	HP = Hume Pipe
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP + 1/Box	
25-34	30	56.30	1:1.5	6.50	1	0	6.10		1.79	19.84	0			7/HP + 1/Box	
35-44	40	63.40	1:2	6.50	.90	.10	8.47		2.34	24.77	.12	2.20		7/HP + 1/Box	
45-54	50	76	1:4	6.50	.70	.30	7.72		3.82	17.55	1.42	5.16		6/HP + 1/Box	Rock or hard soil
55-64	60	80.50	1:6	6.50	.70	.30	11.10		4.62	25.25	1.77	7.26		6/HP + 1/Box	Rock or hard soil
0-14	7	45	1:1	10	.60	.40	.84	.65		2.52	1.30			5/HP + 2/Box	
15-24	20	45	1:1	10	.60	.40	3.43	5.36		10.30	10.72			5/HP + 1/Box	
25-34	30	56.30	1:1.5	10	1	0	9.39		1.78	46.95	0			7/HP + 1/Box	
35-44	40	63.40	1:2	10	.90	.10	13.03		2.57	58.62	.30	2.59		7/HP + 1/Box	
45-54	50	76	1:4	10	.70	.30	11.87		4.77	41.54	3.36	7.70		6/HP + 1/Box	Rock or hard soil
55-64	60	80.50	1:6	10	.60	.40	14.63		7.13	43.90	7.43	16.41		6/HP + 1/Box	Rock or hard soil
MEDIUM HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP + 3/Box	
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP + 3/Box	
25-34	30	56.30	1:1.5	6.50	.90	.10	5.49		2.09	16.07	.09	1.83		8/HP + 4/Box	
35-44	30	71.60	1:3	6.50	.80	.20	6.05		2.77	15.74	.50	2.95	8.52	8/HP + 1/Box	
45-54	50	76	1:4	6.50	.60	.40	6.61		4.41	12.90	2.53	6.67	9.87	8/HP + 1/Box	
55-64	60	80.50	1:6	6.50	.50	.50	7.93		6.21	12.88	4.90	12.47		8/HP + 1/Box	
0-14	7	45	1:1	8	.60	.40	.67	.52		1.61	.83			5/HP + 3/Box	
15-24	20	45	1:1	8	.60	.40	2.75	4.29		6.59	6.86			5/HP + 3/Box	
25-34	30	71.60	1:1	8	.80	.20	4.57		2.54	14.64	.57	2.54	5.43	8/HP + 1/Box	
35-44	40	71.60	1:3	8	.70	.30	6.52		3.51	48.25	1.70	4.44	9.63	8/HP + 1/Box	
45-54	50	76	1:3	8	.50	.50	6.78		5.68	13.57	5.96	10.59	10.29	8/HP + 1/Box	
55-64	60	80.50	1:6	8	.50	.50	9.76		7.13	19.51	7.43	16.11		8/HP + 1/Box	

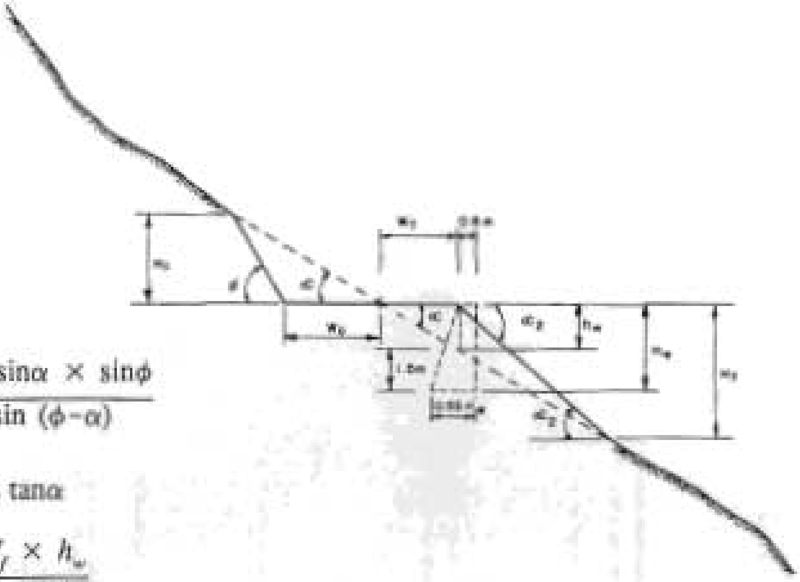
Table 22.13 (Contd.)

Indication Quantities of Major Items of Hill Road for Height of Cut Limited to Less than 12m. and Low Risk Design of Cross Section

HILL SLOPE deg.	AV. SLOPE deg.	CUT SLOPE DEG.	CUT SLOPE H:V	ROAD WIDTH m.	RATIO CUT	RATIO FILL	CUT HT. m.	FILL HT. m.	HT OF RTG. WALL m.	PER KM QUANTITIES: CUT VOL. 1000 cu.m.	FILL VOL. 1000 cu.m.	RETG. WALL VOLUME 1000 cu.m.	BREAST WALL VOLUME 1000 cu.m.	CULVERT No./Type	REMARK
HIGH HAZARD AREAS															
0-14	7	45	1:1	6.50	.60	.40	.55	.42		1.06	.55			5/HP+3/Box	
15-24	20	45	1:1	6.50	.60	.40	2.23	3.48		4.35	4.53			5/HP+3/Box	
25-34	30	71.60	1:3	6.50	.70	.30	3.25		2.71	7.40	.85	2.83	3.24	9/HP+2/Box	
35-44	40	71.60	1:3	6.50	.70	.30	5.30		3.21	12.05	1.12	3.79	6.86	9/HP+2/Box	
45-54	50	76	1:4	6.50	.40	.60	4.41		5.59	5.73	5.88	10.28	5.12	9/HP+2/Box	
55-64	60	80.50	1:6	6.50	.40	.60	6.34		7.01	8.24	7.06	15.60		9/HP+2/Box	
0-14	7	45	1:1	10	.60	.40	.84	.65		2.52	1.30			5/HP+3/Box	
15-24	20	45	1:1	10	.60	.40	3.43	5.36		10.30	10.72			5/HP+3/Box	
25-34	30	71.60	1:3	10	.70	.30	5.00			17.51	2.02	3.79	6.26	9/HP+2/Box	
35-44	40	71.60	1:3	10	.70	.30	8.15			28.52	2.66	5.38	14.04	9/HP+2/Box	
45-54	50	76	1:4	10	.40	.60	6.78			13.57	13.45	17.73	10.29	9/HP+2/Box	
55-64	60	80.50	1:6	10	.40	.60	9.76			19.51	16.72	28.09		9/HP+2/Box	

Notes:

1. Provide vegetative measures for erosion controls in Low Hazard Areas.
2. Provide biotechnical and engineering works for erosion, gully, and minor slides in Medium Hazard Areas.
3. Provide specific landslide stabilization measure based on detailed investigation and analysis for High Hazard Areas.



$$H_c = \frac{W_c \sin\alpha \times \sin\phi}{\sin(\phi - \alpha)} \quad (1)$$

$$h_w = W_f \tan\alpha$$

$$H_f = \frac{W_f \times h_w}{W_f + 2h_w}$$

$$= \frac{W_f^2 \tan\alpha \tan\alpha_2}{W_f \tan\alpha_2 - W_f \tan\alpha}$$

$$= \frac{W_f \tan\alpha \tan\alpha_2}{\tan\alpha_2 - \tan\alpha} \quad (2)$$

$$H_w = W_f \tan\alpha + 0.6 \tan\alpha + 1.5 \quad (3)$$

Cut area

$$A_c = 0.5\ H_c \times W_c \quad (4)$$

Fill area without wall

$$A_f = 0.5\ H_f \times W_f \quad (5a)$$

Fill area with wall, A_{fw},

$$= W_f \tan\alpha\ [0.5\ W_f - \frac{0.25\ W_f \tan\alpha}{1 + 0.5 \tan\alpha}]$$

$$= 0.5\ W_f^2 \tan\alpha - \frac{0.25\ (W_f \tan\alpha)^2}{1 + 0.5 \tan\alpha} \quad (5b)$$

Qtty. of Retaining Wall

$$Q_R = \frac{0.6 + 0.55 \times (W_f \tan\alpha + 0.6 \tan\alpha + 1.5}{2} \times (W_f \tan\alpha + 0.6 \tan\alpha + 1.5) \quad (6)$$

Qtty. of Breast Wall

$$Q_B = (0.5H_c + 0.15H_c^2) \quad . \quad (7)$$

Fig. 22.1 Calculation of quantities of major items of hill road

Table 22.14 Geometric standards for hill roads

DESIGN PARAMETERS	AADT >2000 VF VG CS RS	AADT 1000–2000 VF	VG	CS	RS	AADT 500–1000 VF	VG	CS	RS	AADT 200–500 VF	VG	CS	RS	AADT 50–200 VF	VG	CS	RS	AADT < 50				REMARKS
1) DESIGN SPEED, KPH	HIGH STANDARDS, MY JUSTIFY TUNNELS, CROSSING A RIVER MORE THAN ONCE, ETC. EXTENSIVE STUDY REQUIRED	60	50	40	50	50	40	40	50	50	40	30	40	40	30	30	40	40	25	25	30	1) *ALMOST IMPOSSIBLE TO PROVIDE REQUIRED SIGHT DISTANCE FOR SINGLE-LANE ROAD IN THE HILLY AREAS. EITHER PROVIDE DOUBLE-LANE AT CURVES OR DRASTICALLY REDUCE THE SPEED, PROVIDE MIRROS OR BLOW HORN. 2) FOR TRAFFIC LESS THAN 200 AADT AND AT SECTIONS OF LESS THAN 5% LONG. GRADE, AND PAVED AND SEALED AREAS, OUTSLOPING OF ROAD AT 3 – 4% MAY BE FOLLOWED TO REDUCE FORMATION WIDTH AND CUT VOLUME.
2) TRAFFIC LANES, NO		2	2	2	2	2	2	2	2	2	1+	1+		1	1	1	1	1	1	1	1	
3) CARRIAGE WAY WIDTH M		7	7	7	7	7	6	6	6	7	4–6	4–6	4–6	3.75	3.75	3.75	3.75	3.5	3.5	3.5	3.5	
4) SHOULDER WIDTH, ON EACH, SIDE, M		1	1	1	1	1	1	1	1	1	0.75	0.75	0.75	0.75	0.50	0.50	0.50	0.5	0.5	0.5	0.5	
5) DRAIN, M		1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	1–1.5	
6) MINIMUM ROADWAY WIDTH AT APEX OF SWITCH BACKS/HAIR PIN BENDS		—	11.5	11.5	11.5	—	11.5	11.5	11.5	—	9	9	9	—	7.5	7.5	7.5	6.5	6.5	6.5	6.5	
7) TOTAL FORMATION WIDTH IN M		10–10.5	10–13	10–13	10–13	10–10.5	9–13	9–13	9–13	10–10.5	6.5–10	6.5–10	6.5–10	6.25–7	5.5–9.0	5.5–9.0	5.5–9.0	5.5–8.0	5.0–8.0	5.0–8.0	5.0–8.0	
8) RULING GRADIENT %		3	4	6	5	4	6	6	4	4	6	6	5	4	7	7	6	4	7	7	6	
9) MAXIUM GRADIENT %		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	
10) EXCEPTIONAL GRADIENT %		—	10	10	10	—	10	10	10	—	10	10	10	—	12	12	12	—	12	12	12	
11) GRADE COMPENSATION AT CURVE %; 12) MAXIUM LENGTH OF MAXIUM GRADIENT, M; 13) MAXIUM LENGTH OF EXCEPTIONAL GRADIENT, M		100	100	100	100	100	60	60	60	100	60	60	60	100	60	60	60	100	60	60	60	
14) MINIMUM LENGTH OF RECOVERY, AFTER MAXIMUM OR EXCEPTIONAL GRADE, AS SPECIFIED		200 M @	150M @4%			200 M@ 3%	150M @ 4%			150 M@4%												
15) MINIMUM STOPPING SIGHT DISTANCE, M		90	60	45	60	60	45	45	60	60	45	30	45	45	30	30	45	45	25	25	30*	
16) MINIMUM OFFSET FROM CENTRE LINE TO INSIDE EDGE OF CUT AT 1.2 M HT		14	6.5	5.5	6.5	6.5	5.5	5.5	6.5	6.5	5.5	4.5	5.5	20	16	16	20	20	13	13	16	
17) SUPER-ELEVATION, M		$e\frac{V^2}{127R}$ m/s — 10% ; f 0.14 for 60 KPH to 0.19 for 20 KPH																				
18) VERTICAL CURVE		FORMULAE																				
19) MINIMUM RADIUS OF HORIZ. CURVE, M		120	75	45	75	75	45	45	75	75	45	25	45	45	25	25	45	45	20	20	25	
20) EXTRA WIDENING OF PAVEMENT AT CURVES, M		—	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	

AADT = Average Annual Daily Traffic
VF = Valley—flat
VG = Valley—gorge
CS = Climb Section
RS = Ridge Section

Table 22.15 Preliminary design of cut slopes for heights of cut less than 10 m

Sl.	Type of Soil/rock protection work (vertical to horizontal)	Stable cut slope without any breast wall or minor protection work (vertical to horizontal)	Stable cut slope with
1	2	3	4
1.	Soil or soil mixed with boulders		
	(a) Disturbed vegetation	1:1	n:1*
	(b) -do-overlaid on firm rock	Vertical for rock-portion and 1:1 for soil portion	Vertical for rock portion and n:1 for soil portion
2.	Same as above but with dense vegetation forests, medium rock, and shales	1:0.5	5:1
3.	Hard rock, shale, or harder rocks with inward dip	1:0.25 to 1:0.10 and vertical or overhanging	not needed
4.	Same as above but with outward dip or badly fractured rock/shale	At dip angle or 1:0.5 or dip of intersection of joint planes	5:1
5.	Conglomerates/very soft - shale/sandrock which erode easily	Vertical cut to reduce erosion	5:1

* n is 5 or H<3m; 4 or H = 3-4 m; 3 for H = 4-6 m

Table 22.16 Selection of retaining walls

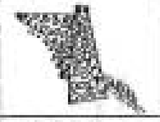
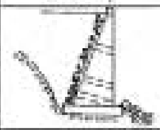
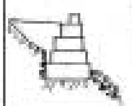
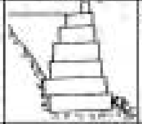
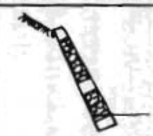
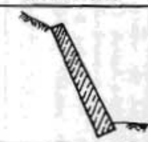
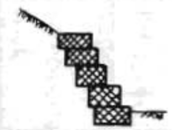
	Type	Retaining Walls						
		Timber crib	Dry stone	Banded dry stone/masonry	Cement masonry	Gabion Low	Gabion High	Reinforced Earth
	Diagrammatic cross-section							
CONSTRUCTION	Top width	2m	0.6–1.0m	0.6–1.0m	0.5–1.0m	1m	1–2m	4m or 0.7–0.8m
	Base width	–	0.5–0.7H	0.6–0.65H	0.5–0.65H	0.6–0.75H	0.55–0.65H	4m or 0.7–0.8H
	Front batter	4:1	vertical	varies	10:1	6:1	6:1	3:1
	Back batter	4:1	varies	vertical	varies	varies	varies	3:1
	Inward dip of foundation	1:4	1:3	1:3	horizontal or 1:6	1:6	1:6	horizontal
	Foundation depth below drain	0.5–1m	0.5m	0.5–1m	0.5–1m	0.5m	1m	0.5m
	Range of height	3–9m	1–6m	6–8m	1–10m	1–6m	6–10m	3–25m
	Hill slope angle	<30°	<30°	20°	35–60	35–60	35–60	<35
	Toe protection in case of soft rock/soil	Boulder pitching	Boulder Pitching					No
NOTES	General	Timbers 15cm Ø with stone rubble wall packed behind timbers. 10% of all headers to extend into fill. Ecologically unacceptable	Set stones along foundation bed. Use long bond stones. Hand packed stones in back fill.	Cement masonry bands of 50 cm thickness at 3m c/c. Other specifications as for dry stone wall	Weep roles 15x15cm size at 1–2m c/c. 50 cm rubble backing for drainage	Stones to be hand packed. Stone shape important, blocky prefreable to tabular. Specify maximum/minimum stone size. No weathered stone to be used. Compact granular back fill in layers (<15cm). Use B type gabion wall.		Granular back fill prefered. Use geogrid for H <4m and tenmar grid for H> 4m. Provide drainage layer in case of seepage problems. Specify spacing of reinforcement grids.
		1. Foundations to be stepped up if rock encountered. 2. All walls require durable rock filling of small to medium size. 3. Drainage of wall bases not shown. Provide 15 cm thick gravel layer in case of clayey foundation.						
Application		Least durable ... Most durable Non ductile structures most susceptible to earthquake damage 1. Design as conventional retaining walls. Assume surcharge on road of 2T/m2. 2. Used both as cut slope and fill slopes support. Breast wall is more economical for cut slope 3. Choice of wall depends on local resources, local skill, hill slope angle, foundation conditions and also shape of back fill wedges as illustrated in diagrams and compatibility of materials				Can take differential settlement and slope movement Very flexible structures		Huge potential used more as stable reinforced fill plateform for road rather than preventive method of slope support.

Table 22.17 Selection of breast walls

TYPE		Breast Walls/Revetment Walls						
		DRY STONE			HANDED DRY STONE MASONRY	CEMENT MASONRY	GABION	HORIZONTAL DRUM WALLS
Diagramatric cross—section								
Construction notes	Top width	0.5			0.5	0.5	2	1
	Base width	0.29H	0.3H	0.33H		0.23H	2	1
	Front batter							
	Back batter	3:1	4:1	5:1	3:1	3:1	3 to 5:1	3:1
	Inward dip of foundation	1:3	1:4	1:5	1:3	1:3	1:5	1:3
	Foundation depth below drain	0.5m	0.5m	0.5m	0.5m	0.5m	0.5—1m	0.25m
	Range of height	6m	4m	3m	3—8m	1—10m	1—8m	2.2m
	Hill slope angle	35—60			35—60	35—70	35—60	35
	Toe protection in case of soft rock/soil	No pitching			No	No	No	No
	General	Pack stone along foundation bed. Use bond stones. Specify minimum stone size.			Cement masonry (1:6) bands of 0.5m thickness at 3m c/c.	Weep holes 15x15 cm at 1.5-2m c/c and grade 1:10. Cement sand mortar (1:6)	Step in front face 20-50cm wide. Otherwise as for retaining walls.	Use vertical single drum for 0.7 m height. Anchor drum walls on sides. Fill debris material.
		Revetment walls have uniform section of 0.5m/0.75m thickness for batter of 2:1 or more. Section shaped to suit variation and overbreak in rock cut slope.						
Application		Least durable/ economical			Little used	Most durable/costly	Quite durable/costlier or Very flexible	Promising/most economical Flexible
		Not ductile structures most susceptible to earthquake damage						
		Revetments are used to prevent only major erosion, rockfall, slope degradation particularly where vulnerable structures are of risk.						

Notes

1. Wall construction requires special skills and practical labour. Curing of masonry walls generally not feasible in hills due to paucity of water.

2. The typical dimensions shown rely both on well—drained backfill and good foundation conditions.

3. Detailed design is necessary in case of soil slopes and walls higher than 6m and poor foundation conditions.

4. Gabion walls should be used in case of poor foundation/seepage conditions. They can take considerable differential settlement and some slope movement.

5. Other measures should also be taken, e.g., check drains, turfing, benching of cut slopes in soft rocks, sealing of cracks, etc. All preventive measures should be implemented in one season. Total system of measures is far more effective than individual measures.

Table 22.18 Design approach for retaining and breast walls at prefeasibility stage

DESIGN METHOD		WALL SIZE		TYPE	HAZARD LEVEL
		HEIGHT, m	AREA, m2		
Thumb Rule		≤3	≤120	D, CM,G	L
(Top width	0.5 to 0.6 m	≤3	≤120	G	H
Bottom width =	0.55 x Hr				
	0.65 x Hr	≤3	≤120	D, CM,G	L
		≤3	≤120	G	H
Standard		4-8	<120	D, CM,G	L
Drawing		4-8	<120	G	H
		4-8	<120	D, CM,G	L
		4-8	<120	G	H
		>8	<120	CM,G	L
		>8	<120	G	H
		≤3	>120	D, CM,G	H
		4-8	<120	G	H
Semi-		4-8	>120	D,CM,G	L
Empirical		4-8	>120	G	H
		>8	<120	CM,G	L
		>8	<120	G	H
		>8	>120	CM,G	L
		>8	>120	G	H

TYPE OF WALL
D = Drystone Masonry
CM = Cement Stone Masonry
G = Gabion Masonry

OTHER TYPES OF WALL:
Follow Proprietary, or
Semi-empirical or
Theoretical methods
Hr = Height of retaining wall above toe

HAZARD LEVEL OF THE AREA,
L = Low
H = High

Table 22.19 Earthwork estimation at prefeasibility stage

Kilometre	Chainage	Section Type	Slope Degree	Hazard Level	Soil Type	Length, Km	Quantity per Km		Volume	
							Cut	Fill	Cut	Fill
1	2	3	4	5	6	7	8	9	10	11

2 to 7 Arun Hazard Assessment
8,9 from Indicative unit quantities

Table 22.20 Breast wall/retaining wall/river training estimation at prefeasibility stage*

Kilometre	Chainage	Section Type	Slope Degree	Hazard Level	Soil Type	Length Km	Type of wall	Quantity per km m^3			Total Quantity, m^3		
								Foundation excavation	Back-fill	Masonry	Foundation excavation	back-fill	Masonry
1	2	3	4	5	6	7	8	9	10	11	12	13	14

* Separate table for Breast walls and retaining walls required
2 to 6 from hazard assessments
8 from judgements based on hazard
9 to 11 from indicative table of unit quantities

Table 22.21 Culvert estimation at prefeasibility stage

Kilometre	Chainage	Section Type	Slope Degree	Hazard Level	Soil Type	Length (Km)	Type of Culvert	Quantity per Km*			Total Quantity			
								No of culverts	Foundation excavation m^3	Back-fill m^3	Length of pipes m	Span, m	Foundation excavation m^3	Back-fill m^3
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

* From Table of Indicative Unit Quantities

Table 22.22 Drain estimation at prefeasibility stage

Kilometre	Chainage	Section Type	Slope Degree	Hazard Level	Soil Type	Length (Km)	Type of Drain	Quantity per km*			Total Quantity		
								Unlined m	Lined m	Filter m	Unlined m	Lined m	Filter m

* From Table of indicative unit quantities and judgements

Table 22.23 Stabilization estimation at prefeasibility stage

Kilo-me-tre	Chainage	Sect-ion Type	Slope Deg-ree	Haz-ard Level	Haz-ard Area m^2	Haz-ard Type	Per-cent of Haz-ard Area to be Stabi-lized	Type of Stabi-liza-tion	Quantity of stabilization works*										
									Exca-va-tion m^3	Fill-ing m^3	Mas-onry m^3	Sur-face Drains m	Fil-ter Drains m	Hori-zon-tal Drains m	Verti-cal Drains m	Rock Bolt-ing m	Wire Nett-ing m^2	Plan-ta-tions m^2	Vege-ta-tion m^2
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

* From judgements based on hazards and type of proposed stabilization.

Table 22.24 Summary of earthwork quantities

Valley Section*
Climb Section
Ridge Section

Slope, degree	Chainages	Lengths Km	Hazard Levels	Filling in m^3	Cutting in m^3										
					Soil						Rock				Total in Cutting
					Eluvium		Alluvium		Colluvium		Highly fractured	Highly weathered	Medium-weathered and fractured	Sound rock with high joint spacing	
					Soft	Hard	BM	Cemented Conglo-merates	Soft	GM					
0-5															
6-14															
15-24°															
25-34															
35-44															
45-54°															
55-60°															
> 60															

* A table for each type of section will be required

Table 22.25 Summary of quantities of breast walls

Valley Section*
Climb Section
Ridge Section

Slope of Road Section (Degree)	Chainages	Lengths	Hazard Levels	Wall Size LxBxH	Quantities (M 3)						
					Foundation Excavation	Drystone Masonry	Bonded Masonfy	Gabion Masonry	Cement Masonry	Reinforced Earth	Others
Plain 0-5											
Rolling 6-14											
15-24											
25-34											
35-44											
45-54											
55-60											
> 60											

* A table for each type of section will be required

Valley Section*
Climb Section
Ridge Section

Slope of Road Section (Degree)	Chainages	Lengths	Hazard Level	Quantities (M 3)						
				Foundation Excavation	Drystone Masonry	Bonded Masonry	Gabion Masonry	Cement Masonry	Reinforced Earth	Others
Plain 0-5										
Rolling 6-14										
15-24										
25-34										
35-44										
45-54										
55-60										
> 60										

* A table for each type of section will be required
** Use separate table for river training works

Table 22.27 Summary of quantities of culverts

Valley Section*
Climb Section
Ridge Section

Slope in Degree	Chainage	Length	Hazard Level	Type	Size	Quantities (M 3)					
						Foundation Excavation	PCC	RCC	Pipes	Masonry	
										Gabion	Cement
Plain 0-5											
Rolling 6-14											
15-24											
25-34											
35-44											
45-54											
55-60											
> 60											

Table 22.28 Summary of quantities of side drains and catch drains

Valley Section*
Climb Section
Ridge Section

Slope in Degree	Chainage	Length	Hazard Level	Side Drains			Catch Drains		
				Lined Surface Drain	Unlined Surface Drain	Filter Sub-surface Drain	Lined Surface Drain	Unlined Surface Drain	Filter Sub-surface Drain
Plain 0-5									
Rolling 6-14									
15-24									
25-34									
35-44									
45-54									
55-60									
> 60									

* A table for each type of section will be required

Table 22.29 Summary of quantities of erosion control works in the watershed area influencing the road

Valley Section*
Climb Section
Ridge Section

Slope in Degree	Chainage	Length	Hazard Level	Stabilization Area	Hazard Area	Check Dams			Biotechnical Works		
						Gabion Masonry	Cement Masonry	Others	Vegetation	Plantation	Others
Plain 0-5											
Rolling 6-14											
15-24											
25-34											
35-44											
45-54											
55-60											
> 60											

* A table for each type of section will be required

Table 22.30 Summary of quantities of landslide stabilization works

Slope in Degree	Chainage	Length	Hazard/Risk Level	Hazard Area, m^2	Stabilization Area m^2	Size LxBxH (Landslide)	Excavation, m^3	Filling, m^3	ENGINEERING											Others
									Walls, Buttresses				Rock Bolting	Drains			Biological			
									Dry Masonry m^3	Drum Wall m^3	Gabion Masonry m^3	Cement Masonry m^3		Horizontal Drains m	Vertical Drains m	Filter Drains m	Vegetation m	Plantation m	Geotextile m^2	
Plain 0-5																				
Rolling 6-14																				
15-24																				
25-34																				
35-44																				
45-54																				
55-60																				
> 60																				

22.2.8 *Initial Environmental Examination (IEE)*

An initial environmental impact examination is suggested at the prefeasibility stage. Table 22.31 is a sample checklist/questionnaire to determine whether a detailed Environmental Impact Assessment (EIA) is necessary.

Table 22.31 Initial Environmental Examination (IEE)

1. Natural Processes

State of Nature and Dangers	Details				Remarks
	Year	Location	L x B x D	Likely Road Length Affected	
o Landslides, m^3 o Gullies, m^3 o River undercutting, m^3 o Forest cover, m^2 o Glacial lakes affecting the road, nos o Landslide-dams, nos o Major earthquakes o Rainfall, mm > ... mm Average Annual max. ..... mm, 24 hr max. ..... mm, 3 day o Frequency of landslide occurrence o Frequency of GLOF o Frequency of landslide damming and outburst floods					

2. Road Activities

Activities	Details required
o Approximate per km cost	
o Road formation	- Full bench, cut and fill, full fill
o Method of disposal of cut material	- Side casting, end haul at safe places
o Net positive impacts	
o Net negative impacts	
o Need for detailed EIA	
o Maximum height of cut in rock	- metres

Activities	Details required
o Maximum height of cut in soil	- metres
o cutting in dip slopes >20° and < 90°	-
o Blasting	- Hand-holes, compressor and drill, split blasting, uncontrolled blasting
o Construction materials - stone, sand	- river, hill, quarry
o Rock structure at hill quarry	- Dip slope, counter dip slope, highly fractured, less joints and fractures
o Compensation - project-affected families - land acquisition - hardship	- Nos - Market rate, govt. rate, no compensation - Included, not included
o Acquisition of unstable land beyond the right of way but influencing the road	- Area
o Erosion controls at the outfalls	- All outfalls, only important outfalls
o Forest clearance	- No. of trees to be felled, area
o Vegetation o Plantations	- Area - No. of trees, Area
o Use of firewood for labour camp	- Yes, no
o Use of firewood for roadworks	- Yes, no
o Pavement surface	- Sealed (full width, carriageway) gravelled, dirt, out-slope, inslope
o Interference with other existing activities effect on irrigation canals	- Length in m, irrigated area adversely affected
o Existing buildings endangered Other structures endangered	- Nos. - Nos.
o Interference with ecology major rare species (fish, plants, animals) likely to be lost	- Type and content
o Interference with archaeological and cultural values	- Description

22.2.9 *Socioeconomic Assessments*

A road transport feasibility study is a planning process that involves two levels: namely, macro-level and micro-level. Overall transport planning at the national, regional, or local level is necessary to identify alternative modes of transport at the macro-level. Road transport planning, based on overall transport planning at national, regional, or local level, is then necessary to identify the road networks at macro-level. This is helpful in developing road transport master plans. Network analysis becomes particularly useful in this exercise. Micro-level feasibility is a project-level feasibility study that is needed to select the most appropriate alternative from several choices identified by network plans.

Feasibility studies at any level require a set of criteria. At the macro-level, criteria such as road density, connectivity, unit costs, socioeconomic parameters, and strategic considerations are of appreciable concern. Among the micro-level criteria, cost effectiveness is normally a major concern.

Ideally, it would be desirable to transform all considerations involved into monetary terms and analyse them in terms of benefits and costs. Complete economic treatment, however, is hardly possible for rural development projects in developing countries. Economic analysis based on quantifiable benefits and costs only is, therefore, of limited value in feasibility decisions for road projects aimed at rural development. Nevertheless, economic micro-level analysis can be meaningful for certain considerations and thus should be an important aspect of the prefeasibility study, particularly at the micro-level.

Problems

The following issues relate to road feasibility in the mountainous areas of developing countries.

- Absence of carefully worked out transportation master plans creates a tendency to expect answers to all problems related to wider aspects of planning from a project-level feasibility study. It may, therefore, compel the agency carrying out the feasibility study to evolve, on its own, criteria on major development strategies. The time, money, manpower, and data normally possible for such feasibility studies will enable them to do no more than make oversimplified assumptions that may either result in misleading conclusions or subject the study to open and unstructured criticisms from several quarters.

- It is a well-known fact that improvements in access roads should be accompanied by investments in key sectors to create conditions favourable for rural development. The treatment of this fact in economic analysis requires care. Specifically, the identification of costs and benefits, resulting from the complementary investment in the road and rural development, should not be biased. Treating roads as a cost only for an integrated development scheme ignores the relationships between rural development and direct benefits to road users, resulting in a total absence of understanding regarding the implications for road alignment, standards, technology, maintenance policy, and upgrading plans. Similarly, excluding rural development investments and benefits from the road investment analysis ignores the indirect benefits arising from impacts of the road in the influence area, thereby underestimating the value and standard of the transport facility. Problems of measuring direct and indirect benefits occur only after defining the approaches, objectives, and criteria for a road-related investment. Thus, the first concern should be with defining the method of economic planning.

- Most roads that are being upgraded, that are under construction, or that are planned for immediate construction could be classified as rural access roads because of the subsistence agricultural areas which the roads span. However, these roads ultimately function as arterial or collector types for three reasons: (1) they constitute the basic network connecting the administrative centres throughout the country, (2) they have high per kilometre costs, and (3) there is always the likelihood of a considerable traffic growth rate to levels beyond low-volume designs. In this context, road planning is faced with the problem of designing a road under growing travel demand. The standard of a road, which the demand justifies, is subject to change. Deterioration of, or lack of improvement in, the standard can cause loss of economic potential. The economic planning exercise should be cognizant of such factors, i.e., the growth of travel demand should be adequately accounted for.

- Budget constraints caused by competing investments in other projects often result in low capital outlays for maintenance. Over time this practice results in an uneconomic loss of road standards and benefits to road users. High costs, that could have been avoided by timely maintenance, are incurred in rehabilitation, while user benefits simply lapse. Economic analysis should clearly show the economic motivation for timely maintenance plans and illustrate the losses resulting from any departures from the maintenance plan.

- Frequently roads evolve out of investments made by different agencies and programmes. Initially road projects begin with voluntary labour with little or no support from the central level. Even at the central level, projects are seen to start without detailed investigations and with nominal budget provisions. Projects continue for several years - continuously or intermittently under separate programmes, or a combination of programmes, such as people's participation projects, integrated development projects, district level projects, and centrally run sectoral or multi-sectoral projects. When the road comes under the jurisdiction of the Road Department Agency, aside from the difficulties in comprehending the overall design and economic plan of the road, there will be reasons that lead to the abandonment of the existing facility or bias the alignment, design, construction standards, and the feasibility of upgrading the road. It is necessary to assimilate the investments made by the various organisations, during the evolution, into a long-run economic plan of the road. The preparation of such an economic plan at the outset of the project should clarify the stages of evolution within which investments made contribute towards an economically efficient road development.

- Roads in the hilly areas face risks because of hazards created by natural forces. Construction and maintenance costs, as well as benefits, are affected by risks. The uncertainty introduced by the risks affects the economic viability of alternatives. Risk assessments should be incorporated into the economic analysis in order to realistically account for costs and benefits.

Guidelines on Prefeasibility Economic Analysis

- Criteria for feasibility should have a bearing on overall transport planning specific to the level of road network rather than the source of funding.

- Economic analysis should constitute one of the several criteria for feasibility decisions rather than being a decision in itself.

- Hill roads of considerable length, say in excess of 25 km, owing to their high construction and maintenance costs and severe instability problems, must be thoroughly studied in terms of technical feasibility and realistic cost projections before carrying out economic analysis.

- Economic analysis of medium roads may be conducted by cash flow analysis.

- Roads built with the objective of rural area development are faced particularly with the need for thoroughly assessing indirect benefits. The difficulty of assessing indirect benefits could be overcome by ignoring such an assessment, provided the relevant alternatives involved are likely to result in the same degree of indirect benefits owing to their similarity in characteristics of development potential (such as natural resource endowments, population, production patterns, and income levels). However, this is not possible where a single alternative only is involved in the analysis.

o Rapid collection of socioeconomic data from existing sources and field visits should be done for economic analysis during the prefeasibility stage.

22.2.10 *Selection Process*

The comparison of alternatives is done by the use of weightages of various criteria of selection and ranking of the alternatives. Table 22.32 is a checklist for the site-selection process. Table 22.33 is an example of the selection process. The weightages for relative importance have to be predetermined and approved by a competent decision maker.

22.3 MAJOR ROADS

Prefeasibility assessments for major roads should be similar to those of medium roads. The only differences between them may be that the number of alternative routes to be investigated may be fewer and the extent of risk mitigation measures of necessity may be higher than those of medium roads because of the higher traffic volume on the major roads.

Comparison of alternatives in this case should focus attention on technological alternatives rather than on the number of major route alternatives. Shorter road lengths, higher design speed, and uninterrupted serviceability should be more important considerations for these roads.

22.4 HIGH STANDARD ROADS

These roads generally become necessary when economic activities develop in the areas around the road points and when, as a result, there is a need to upgrade the existing road. Shorter road lengths, higher design speeds, higher geometric standards, and higher levels of technological inputs in the construction and maintenance are the considerations for such roads.

Use of tunnels, several crossings for the same river, and high standard, engineering stabilization works, such as rock bolting, buttresses, and horizontal drains, need to be considered for these roads. Investigations and designs for these roads require more rigorous treatment - not specifically covered in this handbook.

Table 22.32 Comparison of alternatives

Parameter		Alternative 1	Alternative 2	Alternative 3
Cost				
Construction Cost	Undiscounted			
	Inflated and undiscounted			
Maintenance Cost	Undiscounted			
	Inflated and undiscounted			
User Cost	Undiscounted			
	Inflated and undiscounted			
Construction Period				
Design Life				
Economic Analysis	NPV with reference to base line alternative			
	B/C with reference to base line alternative			
	IRR with reference to base line alternative			
Hazard Level				
Risk Level				
Environmental Impacts				

Source:

NPV = Net Present Value
B/C = Benefit/Cost
IRR = Internal Rate of Return

Table 22.33 Illustrative method for selecting site/alignment alternatives

	CRITERIA									
	Initial Cost	Maintenance Cost	Duration of Construction	Design Life	Hazards and Risks	Economic Return	Environmental Impacts	Strategic or other Consider-ation	Total Rating	Rank
Relative Importance	10%	10%	10%	10%	20%	15%	15%	10%	100	
Alternative 1	100/10	0/0	90/9	40/4	0/0	70/10.5	0/0	100/10	43.5	8
Alternative 1A	80/8	10/1	80/8	50/5	10/2	80/12	20/3	100/10	49	6
Alternative 1B	50/5	20/2	70/7	50/5	20/4	70/10.5	30/4.5	100/10	48	7
Altrnative 2	80/8	60/6	60/6	70/7	30/6	80/12	50/7.5	50/5	57.5	4
Alternative 2A	70/7	50/7	60/6	80/8	50/5	70/10.5	60/9	50/5	57.5	4
Alternative 2B	60/6	40/4	50/5	80/8	60/6	70/10.5	70/10.5	50/5	55	5
Alternative 3	50/5	80/8	50/5	90/9	70/7	70/10.5	90/13.5	20/2	60	2
Alternative 3A	40/4	80/8	40/4	100/10	80/8	60/9	90/13.5	20/2	58.5	3
Alternative 3B	30/3	100/10	40/4	100/10	100/10	50/7.5	100/15	20/2	61.5	1

Source:

Note:

- Criteria and relative importance to be decided at policy level.
- For each criterion assign points out of 100. If least problem assign 100 points. High problems assign 0, intermediate problems use best guess.
- Multiply the point of each criterion by relative importance and indicate the value in the denominator.
- Add values of all criteria in the denominator and indicate the total value under total rating.
- Rank the alternative with highest score as No.1 priority and so on.