HIS MAJESTY'S GOVERNMENT OF NEPAL
MINISTRY OF WORKS AND TRANSPORT
DEPARTMENT OF ROADS

DEPARTMENTAL POLICY DOCUMENT

# DESIGN STANDARDS FOR FEEDER ROADS

(THIRD REVISION)

August 1997

# Foreword

With the objectives of achieving consistency in road design and construction, the Nepal Road Standards (2027) was introduced in B.S. 2027 (1970 A.D.). Subsequently revisions were carried out in B.S. 2045 (1988 A.D.) and 2051 (1994) to incorporate certain changes which were relevant at the time of revisions. The present revision incorporates recent developments in road safety standards for Nepal and additional bioengineering and geometric design elements.

Road construction continues to hold a high priority among the development priorities of Nepal. The government has the objective of constructing feeder roads to every district headquarters not yet linked by road. To date there has been steady but rather slow progress in reaching this objective. Budget constraints are acute due to large number of development projects which demand attention and funding despite the scarcity of resources. Thus it is vitally important that the feeder roads standards should promote the construction of feeder roads in the most economical and practical way possible and make the best use of appropriate technology. They must also be consistent with our policy of "Affordable Risk Management" which gives greater priority of funding to the most heavily trafficked roads. In the light of these objectives the existing design standards for feeder roads have been revised through intensive consultation within the Department and with our consultants. It is expected that the revised standards will assist the Department, and other agencies concerned with construction of rural roads, in carrying out the construction in the most economical way and to an appropriate technical standard. It is hoped that this document will be conducive to achieving the government's objective of connecting the remaining District Headquarters to the national network of transportation in the future.

While selecting the design standards for feeder roads, it is important to note that costly investment mistakes can be avoided by:

a) Framing a detailed project design and project financial formulation minimising the risks associated with the present road construction project preparation. It is most important that a detailed multi-year financial planning and construction schedule of the facility be prepared in order to achieve the best possible return of the investments made in the road construction sector; and

b) Monitoring the traffic and the financial and social benefits achieved by the low cost feeder road construction and decide in due time - based upon factual, reliable data rather than projected, often unrealistic estimates - on the improvement of the road to a higher standard.

Any comments or suggestions regarding the improvement of this standards will be highly appreciated by the Department.

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# 1. General Roads Classification

The Road Classification (Second Revision) 2050 provides for five classes of road in Nepal:

(I) **National Highways (NH)**

National Highways are the main Highways connecting East to West, North to South and those joining the main, north-south valleys of the Nation. The roads connecting NH to Regional Headquarters are also classified as National Highways. These serve directly the greater portion of the longer distance travel, provide consistently higher level of service, and bear the inter-community mobility (regional interest). These roads are the main arterial routes passing through the length and breadth of the country as a whole.

(11) **Feeder Roads (FR)**

Feeder Roads are important roads of a more localised nature than National Highways (NH). Feeder Roads are of secondary nature in the hierarchy of the road network. Feeder Roads are further classified into Feeder Roads (Major) and Feeder Roads (Minor).

The Feeder Roads (Major) /FRN comprise:

- major links (i.e. with an AADT of over 100 veh/day) between the National Highways (NH);
- roads linking District Headquarters/Zonal Headquarters to the National Highways (NH);
- links from National Highways (NH) to the major places of industry, tourism, public utilities and power generation (e.g. hydropower), etc.

The Feeder Roads (Minor) /FRO comprise:

- links from Feeder Roads (FRN) to the major places of industry, tourism, public utilities and power generation (e.g. hydropower), etc.;
- links from Urban Roads (UR) to the major places of industry, tourism, public utilities and power generation e.g. hydropower, etc.

(III) **District Roads (DR)**

District Roads are defined as those roads within the district which serve primarily by providing access to abutting land carrying little or no through movement. These roads give access to one or more villages to the nearest market or higher classes of roads.

(IV) **Urban Roads (UR)**

Urban roads within the urban limit of municipality boundary, except for the above classes, passing through the city. These roads provides access to abutting residential, business, and industrial places within the municipalities.

(V) **Village Roads (VR)**

Village Roads include short non-through roads linking single villages directly to the District Roads.

In order to effectively manage a road network and the traffic using it and to make the best use of available resources, the classification of roads on the basis of functional and administrative importance is necessary for the present network planning. Accordingly the functional importance of the roads as classified in five classes are defined below.

a) **The Strategic Road Network -** comprising National Highways and Feeder Roads. Roads in this network are the main responsibility of DOR.
b) **The District Transport Network -** comprising District Roads, Main Tracks and Main Trails.
c) **The Urban Road Network -** comprising all non-Strategic Roads within the municipal boundaries.
d) **The Village Transport Network -** includes short non-through roads, tracks and local trails linking single villages to the District Transport Network.

There are, at present, 15 Highways and 51 Feeder Roads completed or under construction in Nepal with a total length of some 5,400 km.

## 2. Development Stages of Construction for Feeder Roads

In constructing feeder roads, the concept of Stage Construction shall be applied with clearly defined construction stages and using objective criteria for determining the entry stage for new road construction, and the point at which upgrading to the next stage takes place. Appropriate design and construction standards can then be assigned to each stage. Five development stages are laid down in this document and these should, in general, be implemented in succession.

**Stage I, Detailed Design and Project Formulation (DDPF)** - is the preparation stage covering the planning, engineering design, costing and construction programming of the road or upgrading works;

Stage 11, Fair Weather Earth Track (FWET) - is the initial construction stage representing a basic level of dry season vehicular access;

**Stage 111, Fair Weather Gravel Track (FWGT)** - represents a construction stage to improve the road to dry season access of gravel standard;

Stage IV, All Weather Gravel Track (AWGT) - represents a construction stage to improve the road to allweather access of gravel standard with the provision of structures to ensure only minimum restrictions to traffic at stream crossings;

**Stage V, All Weather Bitumen Road (AWBR)** - represents a construction stage to improve the road to allweather access of bitumen standard with the provision of structures to ensure only minimum restrictions to traffic at stream crossings,

Stage I (DDPF) must precede all other stages and special emphasis must be placed on this stage to ensure that:

- the road is planned to meet present serviceability requirements which will establish the Development Stage of the road;
- the design of the road is in accordance with the standards relating to the particular Development Stage;
- the resources needed for construction and maintenance of the road are identified together with methods of implementation;
- construction is carried out in accordance with the standards and to an agreed programme.

If the potential benefits of the road are to be realised, ***it is most important that construction does not commence until Stage I is complete***. Resources for construction and maintenance will then have been identified and committed, and a realistic construction programme should have been prepared.

As development proceeds and traffic increases, the decision to upgrade a particular road shall be based on the level of total transport costs (the sum of road construction and maintenance costs and vehicle operating costs) for each Development Stage of construction. Threshold traffic values have been developed for this purpose and are given in section 4. The values relate to actual traffic levels on the road. These threshold levels are average figures for roads built in the Hills and the Terai and represent a "trigger point" for initiating a more detailed feasibility study. The decision to upgrade a particular road will be made on the results of the detailed study.

The design standards for different Development Stages of construction are given in section 3. It is particularly important for road safety reasons to ensure that all design elements are upgraded when moving to the next stage.

# 3. Design Standards for Feeder Roads

The concept of stage construction for Feeder Roads in Nepal shall follow the principle that, wherever possible, each construction stage shall be utilised in subsequent upgrading. In practice, this means progressive improvements will be limited to the pavement, drainage and engineering structures thus providing increased stability and permanence of the road as development proceeds. On this basis, the aim should be to establish the alignment and complete the majority of earthworks in Development Stage II (FWET). In order to achieve economies in costly hill road construction and to reduce investment risk for low trafficked hill roads, the feeder road standards have been further sub-divided as follows.

**a) Truck Standards** - the general standard for all Feeder Roads in the Terai, and Feeder Roads in the Hill **Areas with traffic** levels greater than 50 AADT (Average Annual Daily Traffic).

**b) Tractor/Trailer Standards** - a minimum standard for Feeder Roads in the Hill Areas having traffic levels less than 50 AADT.

## a. <u>Truck Standards</u>

Truck Standard is the general standard for Feeder Roads and is applicable for all roads in the Terai, and roads in the Hills having traffic levels above 50 AADT, where truck and bus access is an essential **requirement.** In determining suitable design standards, consideration shall be given to the following factors.

**Alignment and Geometrics**

- Feeder Roads provide a basic means of vehicular access for relatively low traffic levels (up to about 300-400 vehicles per day); therefore, apart from possibly road width and gradient, geometric standards have much less importance than the permanence of the road.
- The alignment shall be chosen carefully to ensure good drainage; additionally, in hilly terrain, earthworks and disturbance to the terrain should be minimised.
- Shoulder widths may need to be increased on sections where there are large numbers of pedestrians and non-motorised vehicles. Surveys of such movements should be made to provide an objective basis on which to make design decisions.
- The alignment must provide drivers with an adequate view of hazards ahead, including areas of high pedestrian activity such as villages. Where this is not possible, good advance signing will be essential and some form of speed reduction device may need to be introduced where speeds are high. Special consideration should be given to narrow bridges, bridges on bends and bends themselves.
- In flat terrain, the cost of road construction and upgrading is largely independent of the alignment; therefore, separate design standards shall be adopted for flat terrain and hilly terrain.
- Geometric standards for each construction stage are defined in Table I (Hilly Terrain) and Table 2 (Flat Terrain) and these have been chosen on the basis of safety and minimal construction and maintenance costs.
- Where feasible, horizontal curves and summit vertical curves shall be kept to the minimum desirable radius and as short as possible. The aim is to provide the maximum length of road where sight distances are sufficient for safe overtaking. Consequently, horizontal curves and summit curves shall generally be kept to the minimum **desirable radius and be as short as possible.** However, care must be taken to avoid having a tight curve after a long straight as this will greatly increase the risk of accidents.
- Consistency of standards shall be maintained over short distances of 5-15 kin to reduce the risk of accidents. The design should also try to ensure that speeds on successive elements do not differ by more than about 15 km/hour.

- Where steep gradients in excess of 7% are adopted, they should be followed by a minimum length of recovery section of 150 metres. The gradient of the recovery section should be 4% (hilly terrain) and 3% (flat terrain).
- Attention should be paid to incorporating carriageway widening on tight curves. The extent of the widening will depend on the traffic and the nature of the curve and is particularly important for paved roads. Similar attention should be given to avoiding adverse crossfall on the carriageway.
- Provision shall be made in hilly terrain for passing places by means of an additional lane 60 metres long and 3.0 metres wide located every 300 to 500 metres along the road.

**Earthworks**

- The majority of earthworks must be completed under Development Stage Il (FWET).
- Earthworks are costly and shall be kept to a minimum in the Hills and Terai. The use of labour-based operations has a major advantage in this respect in that excavation and filling can be carried out more selectively, to much closer tolerances and with less disturbance than by machine.
- For safety reasons, embankment side slopes should be kept as flat as possible (preferably I in 4 or shallower), for at least within 2 metres of the outer edge of the shoulder. Where this is not feasible, consideration should be given to providing some sort of warning device such as delineator posts when the embankment height reaches 2 metres, and safety barriers when the height, exceeds 3 metres.
- An earthworks balance shall be achieved through cross movements rather than extensive longitudinal movements by:
    - locating smaller borrow pits at frequent intervals;
    - arranging borrow areas alongside fill sections;
    - locating the road in sidelong ground rather than through deep cutting.

To avoid ponding, borrow pits should be drained to the nearest natural water course (k-hola).

- The level of compaction applied to fill sections shall be governed by considerations of overall stability rather than the more onerous reduction of settlement at subgrade level.
- In all cases the subgrade (pavement surface in the case of earth roads) shall be a minimum of 300 min above ground level or any standing water including water in the side drain.

**Drainage**

- Adequate provision shall be made for drainage in construction Development Stage II (FWET). The improvements needed in successive stages will largely concern cross drainage such as the replacement of fords by culverted drifts and, eventually, the addition of bridges.
- Side drains must be able to cope with the expected run-off, be capable of being easily cleaned, be traffic-friendly, and not present a serious hazard to run-away vehicles. In easy terrain they should be wide and shallow and as far

from the road as is practicable. Where space is limited and a open channel drain is required it should be preferably flat-bottomed, 400-500 min wide, and no deeper than 350 mm. Where the drains must be larger than this they should be covered, as should all channel drains on roads through villages and towns. In towns and villages consideration should be given to using concrete "tickshaped" open drains as an alternative, in view of their easiness to clean and reduced risk for pedestrians and vehicles. Side drains should be discharged along well defined natural water channels. For details refer **Designing Safer Drains (Road Safety Note 2)** available from the Design Branch, DoR.

- Earthen drains are preferred for the flat gradient section of the road while masonry drains are preferred for the built up areas and the sections of road exceeding 5 % gradient.
- The cleaning of side drains shall be undertaken manually; therefore; the drains should be flat bottomed and be minimum 400 mm wide.
- Pipe culverts with a maximum size of I metre diameter are advisable for handling and to keep earthworks to a minimum; where an increased waterway opening is needed this can be provided by using multiple culvert pipes.
- Stream crossings shall normally be by ford in construction Stages 11 (FWET) and III (FWGT), and by culverted drift in Stage IV (AWGT). Bridges shall be added in Stage IV (AWGT).
- Feeder Roads will have single land bridges. These bridges shall have a minimum overall width of 5.7 metres, consisting of a 4.5 metre carriageway together with 0.6 metre kerbed shoulders supporting a parapet. Advanced warning signs (Road Narrows or Narrow Bridge Ahead) must be installed. Where the bridge is preceded by a sharpr bend, as is commonly the case, this too must be adequately signed. On bitumen-surfaced roads, the use of rumble strips may be effective in alerting drivers to the hazard ahead. (for details regarding protection of foot way and safety measures on construction of bridges refer **DoR Standard Design, DoR Traffic Sign Manual and Road Safety on Bridges (Road Safety Note** 7) available from the Design Branch, DoR.

**Pavement**

- Except in the case of steep gradients and/or highly erodible soils where stabilisation or imported material may be needed, the pavement for construction Stage II (FWET) shall be of natural soil (earth) to provide dry-weather access only.
- Stages III (FWGT) and IV (AWGT) shall provide all-weather access through the addition of a gravel pavement and Stage V (AWBR) through a permanent bitumen running surface.
- An adequate camber shall be provided and maintained on all pavements to remove surface water. Recommended slopes are given in Tables I and 2.
- It is most important in the case of bitumen roads that particular attention is paid to shoulder construction and maintenance. The shoulders are used for passing, parking, by slow moving traffic, and as support for the

carriageway edge. They should be solidly constructed of an erosion resistant material and should not be allowed to fall below the level of the edge of the adjacent carriageway.

**Road Safety Measures**

For the road section having medium to high traffic (> 500 vehicles per -day), the provisions of studs in road bends, safety barrier at hazardous locations, delineator posts, and chevron signs in tight bends should be considered while designing the road. (for details regarding road safety measures on road and road junction and delineation measures refer **DoR Traffic Sign Manual (Road Safety Note 5** & 6) available from the Design Branch, DoR

**Environment Management**

The environmental effects of construction should be considered at every stage from planning onwards. The Department of Roads has published a policy document *(Environmental Management Guidelines)* to simplify this aspect of feeder roads. The main environmental concerns and related to the following areas: quarries; borrow pits; spoil and construction waste disposal; work and labour camps, location and operation; earthworks and slope stabilisation; use of bitumen; stockpiling of materials; explosive, combustible and toxic materials management; setting up and operation of crusher plants; water management; and air and noise pollution. The Department's guidelines should be followed in all of these cases.

**Bio-engineering**

Bio-engineering techniques should be integrated with standard civil engineering measures in all slope stabilisation works. The areas where bio-engineering should be used are:

- all bare soil areas on embankment and cut face slopes;
- all sites where there is a risk of scour erosion *(ie* gullying);
- all slopes where there is a risk of shallow (less than 50 cm deep) debris flows or -translational slips;
- any slope component where other civil engineering structures are employed;
- any area, such as tipping and quarry sites, or camp compounds, where general rehabilitation is required.

For detailed information on the use of bio-engineering, reference should be made to the range of publications produced by the Geo-Environmental Unit of the Department of Roads. The main one of these is the *Roadside Bio-engineering Manual*

Basic Design Standards for Feeder Roads (Truck Standard) covering each Construction Development Stage are given separately for Hilly Terrain and Flat Terrain in Tables I and 2 respectively.

## b. Tractor/Trailer Standards

Feeder Roads (Tractor/Trailer Standard) cover roads connecting District Headquarters, or similar low trafficked roads in the Hills, having predicted traffic levels less than 50 AADT. Minimum design standards have been adopted for these roads. The principle behind the use of the Tractor/Trailer Standard is Ahat the greatest economic benefit produced by a road generally arises when a motorable track is first constructed into an area. Whether subsequent development takes place of sufficient magnitude to justify upgrading the road will depend on many factors and is inherently difficult to forecast. Roads built to Tractor/Trailer Standard are therefore in the nature of a *pilot scheme* to reduce investment risk. They are designed to open-up a region in the Hill Areas at minimum cost by providing basic access for vehicular transport and will, additionally, provide substantive proof of the need, if any, for further investment in road infrastructure to the area.

These standards are designed to provide fair weather earth access only for tractor/trailer units, light trucks (TATA 6.08) and mini buses. At the higher traffic levels, it may be necessary to introduce staggered, unidirectional working. These roads should be closed to vehicular traffic during periods of prolonged rainfall for reasons of safety and to avoid major damage to the road surface.

The Tractor/Trailer Standards effectively comprise a reduction in the **Stage II, (Fair** Weather Earth Track FWET) Truck Standards. In addition to the relevant points made concerning the Truck Standards in section

3a, particular attention shall also be paid to the points set-out below when using the Tractor/Trailer Standards.

- Roads shall be constructed with minimum impact on the surrounding environment. This policy option demands a balanced cut-and-fill earthworks operation. In the absence of a balanced cut-and-fill operation, the resulting surplus cut material will create problems of safe disposal, particularly where the labour intensive methods of construction have been used. In the hills, an alignment utilising side-cut and fill is preferable.
- Traditional methods of construction based on indigenous technology shall generally be adopted. Examples of such methods are given in the DOR Departmental Policy Document: Construction Details for Low Cost Feeder Roads.
- The intention should be to provide each District Headquarters or similar undeveloped area in the Hills with a basic road access to the national network for a minimum capital investment. If the intended development occurs in practice, the road can then be justifiably improved to Truck Standard and higher on the basis of actual traffic demand.
- Steep gradients (above 7%) shall have a gravel surface and shall be followed by a recovery section similar to the requirement for Truck Standards;
- The formation width shall be adjusted to suit the requirements of the complementary longitudinal drainage;
- As for roads to Truck Standard, provision shall be made for passing places by means of an additional lane 60 metres long and 3.0 metres wide located every 300 to 500 metres along the road.
- The pay load of vehicles using the road shall be limited to 3.5 Tonnes (5 Tonnes total weight).
- The basic Design Standards for Feeder Roads (Tractor/Trailer Standard) are given for Hilly Terrain in Table I overleaf.

## DESIGN STANDARDS FOR LOW TRAFFICKED FEEDER ROADS

Table 1. - Hilly Terrain

| | | |
|---|---|---|
| **Development Stage II(i)** | - | **Tractor Standard** |
| **Development Stage II(ii)** | - | **Fair Weather Earth Track** |
| **Development Stage III** | - | **Fair Weather Gravel Track** |
| **Development Stage IV** | - | **All Weather Gravel Road** |
| **Development Stage V** | - | **All Weather Bitumen Road** |

| **DESIGN STANDARD** | **CONSTRUCTION DEVELOPMENT STAGES** | | | | |
|---|---|---|---|---|---|
| | **II(1)** | | **III** | **IV** | **V** |
| Right of way (m) | 30 | 30 | 30 | 30 | 30 |
| Formation width (m) | 4.0 | 4.5 | 4.5 | 4.5 | 4.5 |
| Carriageway width (in) | 3.5 | 4.5 | 3.5 | 4.5 | 3.5 (surface dressing) |
| Shoulder width (in) each side | 0.25 N/A | N/A | 0.5 (earth) | N/A | 0.5 (gravel) |
| Camber (%) | 5 | 5 | 4 | 4 | 3 |
| Minimum horizontal curve radius (in) | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 |
| Minimum vertical curve radius (in) | 100 | 150 | 200 | 300 | 500 |
| Maximum gradient (%) | 150) | 12(l) | 12 | 12 | 12 |
| Limitation of the maximum gradient length (in) above average gradient of 7% | 200 | 300 | 300 | 300 | 300 |
| Maximum recovery gradient (%) to be applied after gradients in excess of 7% for a minimum recovery length of 150 in. | 4 | 4 | 4 | 4 | 4 |
| Passing zones (60m x 3m) | Minimum 2 to 3 per krn | Minimum 2 to 3 per km. | Minimum 2 to 3 per km | Minimum 2 to 3 per km | Minimum 2 to 3 per km |
| Hairpin Bends<br>- Min spacing between centres of bends (in)<br>- Min transition curve length (in)<br>- Max Superelevation (9/4)<br>- Min carriageway width at apex(m)<br>- Max approach gradient for a minimum length of 35 m (%) | <br>100<br>15<br>10<br>7.5<br>5 | <br>100<br>15<br>10<br>7.5<br>5 | <br>100<br>15<br>10<br>7.5<br>5 | <br>100<br>15<br>10<br>7.5<br>5 | <br>100<br>15<br>10<br>7.5<br>5 |
| Minimum culvert size (mm diameter) | 600 | 600 | 600 | 600 | 600 |
| Pavement surfacing | Earth | Earth | Gravel | Gravel | Bitumen |
| Stream crossing | Ford | Ford | Ford | Bridge | Bridge |

(1) Sections exceeding 7% **must be paved with either clay-bound macadam or gravel.**

**DESIGN STANDARDS FOR LOW TRAFFICKED FEEDER ROADS**

**Table 2. - Flat Terrain**

| | |
|---|---|
| **Development Stage II(ii)** | **Fair Weather Earth Track** |
| **Development Stage III** | **Fair Weather Gravel Track** |
| **Development Stage IV** | **All Weather Gravel Road** |
| **Development Stage V** | **All Weather Bitumen Road** |

| DESIGN STANDARD | CONSTRUCTION DEVELOPMENT STAGES | | | |
|---|---|---|---|---|
| | 11(ii) | III | IV | V |
| Right of way (m) | 30 | 30 | 30 | 30 |
| Formation width (m) | 6.0 | 6.0 | 6.0 | 6.0 |
| Carriageway width (m) | 6.0 | 5.0 | 5.0 | 3.5 (surface dressing) |
| Shoulder width (m) each side | N/A | 0.5 | 0.5 | 1.25(gravel) |
| Camber | 5 | 4 | 4 | 3 |
| Minimum horizontal curve radius (M) | 50 | 50 | 50 | 70 |
| Minimum vertical curve radius (m) | 300 | 300 | 500 | 1,000 |
| Maximum gradient (%) | 10(1) | 10 | 10 | 10 |
| Limitation of the maximum gradient length (m) above average gradient of 7% | 300 | 300 | 300 | 300 |
| Maximum recovery gradient (%) to be applied after gradients in excess of 7% for a minimum recovery length of 150 m. | 3 | 3 | 3 | 3 |
| Minimum culvert size (mm diameter) | 750 | 750 | 750 | 750 |
| Pavement surfacing | Earth | Gravel | Gravel | Bitumen |
| Stream crossing | Ford | Ford | Drift/ Bridge | Drift/ Bridge |

(1) Sections exceeding 7% must be paved with either clay-bound macadam or gravel.

# 4. Threshold Traffic Levels for Feeder Road Upgrading

New Feeder Roads will normally be constructed to Fair Weather Earth Track (FWET) Standards, Construction Development Stage II. In order to ensure that the maximum benefits are obtained from the available resources, further capital investment in the road in the form of upgrading, should not be made until additional benefits are assured. This can generally be achieved by upgrading the road only when the combined costs of recurrent and periodic maintenance, together with vehicle operating costs, exceed these same costs on the upgraded road plus the cost of upgrading. As the cost of recurrent and periodic maintenance as well as -total Vehicle Operating Costs will increase with higher traffic levels, the determining factor for upgrading Feeder Roads from one Construction Development Stage to the next is the level of traffic actually using the road.

Use has been made of the World Bank computer-based Highway Design and Maintenance Standards Model (HDM III) to determine the total transport costs (construction/upgrading, maintenance and vehicle operating costs) for a range of traffic levels on earth, gravel and bitumen Feeder Roads. Graphs of total transport costs against traffic levels have then been plotted for each construction standard from which the threshold traffic values for upgrading the road have been determined. Two cases were considered covering Hilly Terrain roads and roads in the Flat Terrain. The resulting graphs and the detailed methodology for deriving them are given in Annex 1.

For simplicity the DoR Working Group has slightly modified the threshold values given by the graph and has recommended the following threshold to be used when assessing the need for upgrading roads.

| **Threshold for:** | **Hilly Terrain** | **Flat Terrain** |
|---|---|---|
| **Upgrading Stage 11 (FWET) to Stage III (FWGT), earth to gravel surface.** | 50 **vpd** | 100 **vpd** |
| **Upgrading Stage III** (FWGT) **to Stage V (AWBR), gravel to bitumen surface.** | 150 **vpd** | 250 **vpd** |

Upgrading gravel surfaced roads from fair weather to all weather, Stage III to Stage IV, should be undertaken before moving to Stage V, bitumen surface. Calculations to determine a suitable traffic threshold for upgrading in this case have not been made but traffic levels midway between the figures given above are considered appropriate.

It is important to note that the threshold levels given are average values and are not intended to be absolute. They have been derived for use:

w as "trigger points" for initiating detailed feasibility studies on a particular road; m in making the case against premature upgrading and the uneconomic use of scarce resources; o for the preparation of 3 year and 5 year rolling plans for new construction works.

In Nepal conditions, upgrading to the next Construction Development Stage should only be considered when actual traffic levels are equal to or exceed the quoted figures.

**ANNEX I**

# Methodology Adopted for Deriving Threshold Traffic Levels for Feeder Road Upgrading

## 1. Highway Design and Maintenance Standards Model

This annex describes the methodology used to derive threshold traffic levels for Feeder Road upgrading which is based on plotting graphs of total transport costs against traffic for three Construction Development Stages as shown in Annex II. The estimation of total transport costs for the three stages has been made by inputting road geometry, road roughness, traffic, and vehicle operating cost data into the Highway Design and Maintenance Standards Model (HDM III) calibrated for Nepal conditions.

HDM III is a computer-based model developed by the World Bank as an economic tool for investigating road construction and rehabilitation alternatives and different road maintenance options. The Model calculates the road user costs on a particular road on the basis of the annual average carriageway deterioration for a given maintenance treatment. The road user cost, added to the maintenance and upgrading costs, together provide an estimate of the total road transport costs for that particular road. The data structure adopted for the model run is described below.

### 1.1 Road Link Characteristics

The road link geometric data given in Table I was input into the Model and is considered representative of Feeder Roads in the Hilly and the Flat Terrain.

Table 1

| **Link Characteristic** | Units | Hilly Terrain | **Flat Terrain** |
|---|---|---|---|
| Link Length | km | 100 | 100 |
| Average Curvature | Degree/km | 500 | 52 |
| Average Rise and Fall | metre/km | 60 | 1.3 |
| Rainfall | metre/year | 0.21 | 0.21 |
| Carriageway Width (earth/gravel) | metre | 4.5 | 6.0 |
| Carriageway Width (paved) | metre | 3.5 | 3.5 |
| Total Shoulder Width (paved) | metre | 1.0 | 2.5 |
| Effective Lane | | 1.0 | 1.0 |

## 1.2 Road Surface Characteristics

The following road surface characteristics have been used for the Model input. It is assumed that planned maintenance activities appropriate to the traffic levels on the road will be carried out.

Earth Road: the initial roughness is taken as 11,000 mm/km (BI).
Gravel Road: the initial roughness is taken as 6,000 mm/km (BI); the maximum size of the gravel material is taken as 75 mm with a plasticity index of 15 for the fines.
Bitumen Road: the initial roughness assuming surface dressing is taken as 4,500 mm/km (BI); the environmental deterioration factor is taken as 0.85; other deterioration factors are the HDM default values.

## 1.3 Cost Input

The costs shown in Table 2 have been input to the Model.

Table 2

| Cost Item | Unit | Roads in Hilly Terrain | | Roads in, Flat Terrain | |
|---|---|---|---|---|---|
| | | **Financial** | **Economic** | **Financial** | **Economic** |
| Spot regravelling | NR/cu in | 1,196 | 1,048 | 1,196 | 1,048 |
| Regravelling | NR/cu in | 1,045 | 916 | 1,045 | 916 |
| Grading | NR/km | 4,470 | 3,921 | 4,470 | 3,921 |
| Patching | NR/sq in | 300 | 263 | 300 | 263 |
| Resealing (surface dressing) | NR/sq in | 98 | 86 | 98 | 86 |
| Routine Maint. (earth) | NR/km | 22,194 | 22,194 | 12,435 | 12,435 |
| Routine Maint. (gravel) | NR/km | 22,194 | 22,194 | 12,435 | 12,435 |
| Routine Maint. (paved) | NR/km | 15,434 | 15,434 | 7,972 | 7,972 |
| Earth Road Construction | NR/km | 3,410,000 | | 1,079,000 | |
| Upgrading Earth-Gravel | NR/km | 1,290,000 | | 913,400 | |
| Upgrading Gravel-Bitumen* | NR/km | 3,230,000 | | 3,741,000 | |

* cost includes upgrading 50% of earth drains in the Hills to masonry. (based on 1996 price)

## 1.4 Traffic Composition

Table 3 contains the traffic composition data used for the Model input.

**Table** 3

| Vehicle Class | Car | Utility | Medium Truck | Empty Truck | Medium Bus |
|---|---|---|---|---|---|
| Composition | 5% | 15% | 45% | 5% | 30% |

## 1.5 Maintenance Policy

The maintenance policies assumed for the Model input are given in Table 4 for routine/recurrent maintenance and Table 5 for periodic maintenance.

Table 4 - Routine/Recurrent Maintenance Activities

| **Traffic Vol.** | **Earth Road** | Gravel Road | Bitumen Road |
|---|---|---|---|
| 20 VPD | - Grading once/yr.<br>- Spot regravelling 8% surface area per yr.<br>- Routine maintenance. | - Grading once/yr.<br>- Spot regravelling 2% surface area per yr.<br>- Routine maintenance. | - Patching 0.5% surface area per yr.<br>- Routine maintenance. |
| 40 VPD | - Grading once/yr.<br>- Spot regravelling 10% surface area per yr,<br>- Routine maintenance. | - Grading once/yr.<br>- Spot regravelling 4% surface ar<br>ea per yr.<br>-<br>- Routine maintenance. | - Patching 0.5% surface area per yr.<br>Routine maintenance.<br>- |
| 60 VPD | - Grading once/yr.<br>- Spot regravelling 12% surface area per yr.<br>- Routine maintenance. | - Grading once/yr.<br>- Spot regravelling 6% surface area per yr.<br>- Routine maintenance. | - Patching 0.5% surface area per yr.<br>- Routine maintenance. |
| 100 VPD | - Grading once/yr.<br>- Spot regravelling 16% surface area per yr.<br>- Routine maintenance. | - Grading once/yr.<br>- Spot regravelling 10% surface area per yr.<br>- Routine maintenance. | - Patching 0.5% surface area per yr.<br>- Routine maintenance. |

**Table 5 - Periodic Maintenance Activities**

| Traffic Vol. | Earth Road | Gravel Road | Bitumen,Road |
|---|---|---|---|
| 20 VPD | Not applicable | - Regravelling Roads in Hilly Terrain every 5 yrs.<br>- Regravelling Roads in Flat Terrain every 6 yrs. | - Resurfacing (SBST) roads in Hilly Terrain every 5 yrs.<br>- Resurfacing (SBST) roads in Flat Terrain every 6 yrs. |
| 40 VPD | Not applicable | - Regravelling roads in Hilly Terrain every 5 yrs.<br>- Regravelling Roads in Flat Terrain every 6 yrs. | - Resurfacing (SBST) roads in Hilly Terrain every 5 yrs.<br>- Resurfacing ~ (SBST) Roads in Flat Terrain every 6 yrs. |
| 60 VPD | Not applicable | - Regravelling roads, in Hilly Terrain every, 5 yrs.<br>- Regravelling Roads in, Flat Terrain every 6 yrs. | - Resurfacing (SBST) roads in Hilly Terrain every 5 yrs.<br>- Resurfacing (SBST) roads in Flat Terrain every 6 yrs. |
| 100 VPD | Not applicable | - Regravelling roads in Hilly Terrain every 5 yrs.<br>- Regravelling Roads in Flat Terrain every 6 yrs. | - Resurfacing (SBST) roads in Hilly Terrain every 5 yrs.<br>- Resurfacing (SBST) roads in Flat Terrain every 6 yrs. |

## 1.6 Vehicle Operating Costs

Cost data updated in August, 1996 by the MRCU has been used for the VOC Model input.

# 2. HDM Model Output

Output data from the Model in terms of Cost of Roads in Hilly and Flat Terrain are given in Tables 6 and 7 respectively. The values in these tables have been plotted to show Total Transport Costs per Kin against Traffic Levels for earth, gravel and bitumen roads. The Threshold Traffic Values for upgrading a road are then determined from the graphs. The graphs have been plotted separately for roads in Hilly Terrain and Flat Terrain and are shown on pages 19 and 20.

ANNEX I

The Threshold Traffic Levels obtained are:

| **Threshold for roads:** | **Hilly Terrain** | **Flat Terrain** |
|---|---|---|
| Upgrading Stage 11 (FWET) to Stage III (FWGT), earth to gravel surface. | 60 vpd | 100 vpd |
| Upgrading Stage III (FWGT) to Stage V (AWBR), gravel to bitumen surface. | 140 vpd | 258 vpd |

## ANNEX I

**Table 6 - Road Costs in Hilly Terrain**

| AADT | Cost NR x 10' per 100 km | | | | Total Transport Costs NRxlO'/km' |
|---|---|---|---|---|---|
| | Capital | Periodic Maint. | Rount./Recurrent Maint. | Vehicle Operating | |
| **Earth Roads** | | | | | |
| 0 | 341.000 | 0.000 | 58.188 | 0.000 | 3.992 |
| 40 | 341.000 | 0.000 | 69.648 | 104.859 | 11.155 |
| 80 | 341.000 | 0.000 | 81.108 | 1420.343 | 18.425 |
| 120 | 341.000 | 0.000 | 92.568 | 2135.827 | 25.694 |
| 160 | 341.000 | 0.000 | 104.028 | 2851.311 | 32.963 |
| **Gravel Roads** | | | | | |
| 0 | 429.000 | 224.964 | 53.328 | 0.000 | 7.073 |
| 40 | 429.000 | 215.966 | 63.628 | 511.811 | 12.204 |
| 80 | 429.000 | 206.968 | 73.928 | 1030.727 | 17.406 |
| 120 | 429.000 | 197.970 | 84.228 | 1549.643 | 22.608 |
| 160 | 429.000 | 188.972 | 94.528 | 2068.559 | 27.811 |
| 200 | 429.000 | 179.974 | 104.828 | 2587.475 | 33.013 |
| **Bitumen Roads** | | | | | |
| 0 | 752.000 | 137.800 | 31.043 | 0.000 | 9.202 |
| 40 | 752.000 | 137.800 | 31.043 | 457.309 | 13.776 |
| 80 | 752.000 | 137.800 | 31.043 | 914.959 | 18.352 |
| 120 | 752.000 | 137.800 | 31.043 | 1372.609 | 22.929 |
| 160 | 752.000 | 137.800 | 31.043 | 1830.259 | 27.505 |
| 200 | 752.000 | 137.800 | 31.043 | 2287.909 | 32.082 |

## Capital Cost

Earth Road: Cost includes earthworks, side drains (earth) and culverts; stream crossings excluded.

Gravel Road: Sunk cost of constructing earth road plus cost of full width gravelling (fair weather).

Bitumen Road: Sunk cost of gravel road plus cost of all weather new DBST carriageway and gravel shoulders plus cost of upgrading 50% of earth drain to masonry.

ANNEX I

Table 7 - Road Costs in Flat Terrain

| AADT | Cost NR x 10' per 100 km | | | | Total Transport Costs NRxlO'/km |
|---|---|---|---|---|---|
| | Capital | Periodic Maint. | RoutinetRecu -rrent Maint. | Vehicle Operating | |
| Earth Roads | | | | | |
| 0 | 107.800 | 0.000 | 36.520 | 0.000 | 1.443 |
| 40 | 107.900 | 0.000 | 42.286 | 496.700 | 6.468 |
| 80 | 107.800 | 0.000 | 48.052 | 997.279 | 11.531 |
| 120 | 107.800 | 0.000 | 53.818 | 1497.856 | 16.595 |
| 160 | 107.800 | 0.000 | 59.584 | 1998.434 | 21.658 |
| Gravel Roads | | | | | |
| 0 | 199.117 | 145.158 | 33.907 | 0.000 | 3.781 |
| 40 | 199.117 | 139.352 | 41.193 | 403.265 | 7.829 |
| 80 | 199.117 | 133.546 | 48.579 | 811.915 | 11.932 |

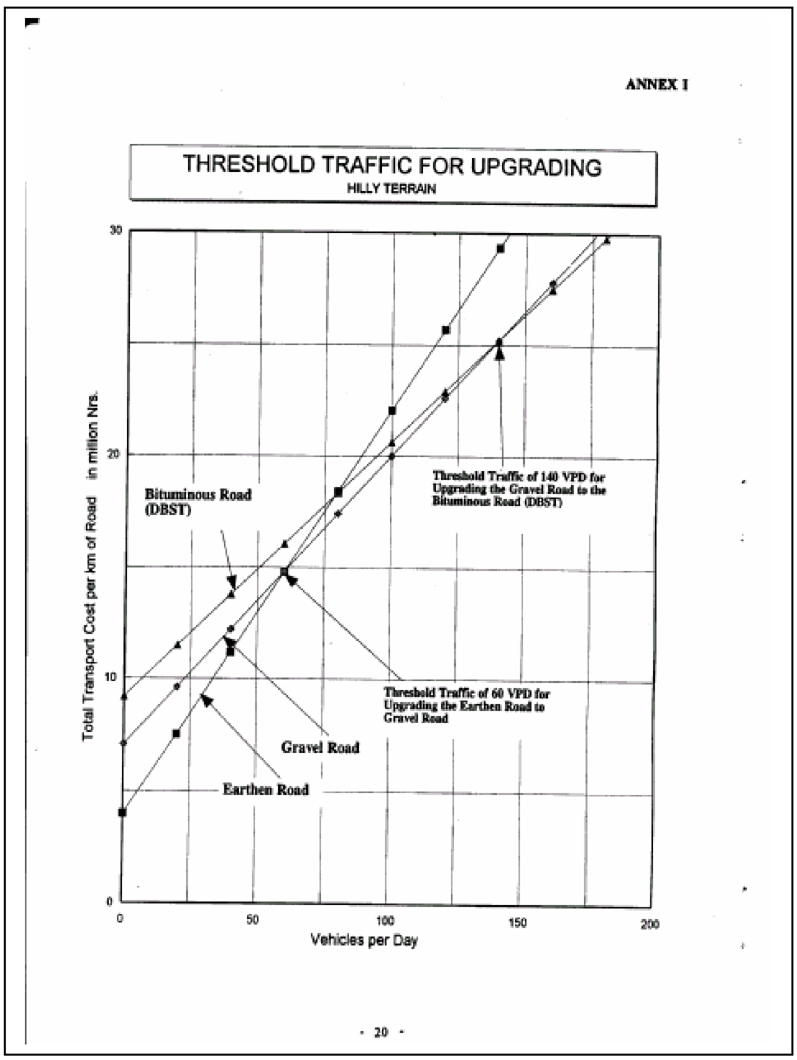
| | | | | | |
|---|---|---|---|---|---|
| 120 | 199.117 | 127.740 | 55.965 | 1220.565 | 16.034 |
| 160 | 199.117 | 121.934 | 63.351 | 1629.215 | 20.136 |
| 200 | 199.117 | 116.128 | 70.737 | 2037.865 | 24.238 |
| 240 | 199.117 | 110.322 | 78.123 | 2446.515 | 28.341 |
| Bitumen Roads | | | | | |
| 0 | 573.221 | 102.900 | 16.467 | 0.000 | 6.926 |
| 40 | 573.221 | 102.900 | 16.467 | 360.398 | 10.530 |
| 80 | 573.221 | 102.900 | 16.467 | 721.028 | 14.136 |
| 120 | 573.221 | 102.900 | 16.467 | 1081.568 | 17.742 |
| 160 | 573.221 | 102.900 | 16.467 | 1442.288 | 21.349 |
| 200 | 573.221 | 102.900 | 16.467 | 1802.918 | 24.955 |
| 240 | 573.221 | 102.900 | 16.467 | 2163.548 | 28.561 |

**Capital Cost**

Earth Road: Cost includes earthworks, side drains (earth) and culverts; stream crossings excluded.

Gravel Road: Sunk cost of constructing earth road plus cost of ***full*** width gravelling (fair weather).

Bitumen Road: Sunk cost of gravel road plus cost of all weather new DBST carriageway and gravel shoulders.



**ANNEX I**

## THRESHOLD TRAFFIC FOR UPGRADING

FLAT TERRAIN