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

DISCUSSION PAPER

ROAD PAVEMENT MANAGEMENT

MRCU

October 1995

LIST OF ABBREVIATIONS

BI	Vehicle Mounted Bump Integrator (for determining road roughness)
DDG	Deputy Director-General, Department of Roads
DE	Divisional Engineer, Department of Roads
DG	Director General, Department of Roads
DOR	Department of Roads
HDM III	World Bank Highway Design and Maintenance Economic Assessment Model
HMG/N	His Majesty's Government of Nepal
HMIS	Highway Management Information System
IRI	International Roughness Index (metres/km)
MOWT	Ministry of Works and Transport
MRCU	DOR Maintenance and Rehabilitation Co-ordination Unit
NPC	National Planning Commission
ODA	British Government Overseas Development Administration
RD	Regional Director, Department of Roads
RMF	Road Maintenance Fund
RMP	Road Maintenance Project (ODA supported component of the RMRP)
RMRP	Road Maintenance and Rehabilitation Project
SDC	Swiss Development Co-Operation
SDI	Visual Surface Distress Index (0-1.7 good, 1.8-3.0 fair, 3.1-5.0 poor)
SMD	DOR Strengthened Maintenance Division
SN	Structural Number (a measure of pavement strength)

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1. INTRODUCTION

Irrespective of the design and construction standards that have been adopted, all road pavements will deteriorate over time. The deterioration is progressive and is influenced by several factors which can be grouped under three main headings:

i) **Environmental** - terrain, climate and local practices.

ii) **Traffic** - volume and axle load.

iii) **Construction** - design and construction standards and quality of materials and workmanship.

Nepal has a particularly difficult environment for road construction and since traffic levels are generally low (maximum ADT 2,200 outside urban areas), the environment is the main cause of pavement deterioration.

The effect of pavement deterioration is a reduction in the serviceability of the road and an increase in costs:

i) to the Government through the premature and rapid depreciation of the large capital investment made in the road;

ii) to the road user through the higher costs of operating and using vehicles on the road as the pavement surface becomes progressively rougher with increasing deterioration.

Loss of serviceability also subjects the road user to considerable discomfort and an increase in journey time which may further add to the cost of using the road. These costs are significant and will justify measures being taken by the Road Agency (DOR) to reduce them, both in the national interest and, especially, in the interest of the road user. At the same time, the measures themselves will result in a cost to the Road Agency. The objective of pavement management is therefore to develop and implement a strategy which provides a reasonable level of service to the road user at a minimum cost to the Agency .

Since vehicle operating costs constitute around 75% to 95% of total road transport costs for traffic levels above 250 ADT, this objective can be expressed by equation 1 as follows:

$$M_C \ll (VOC_1 - VOC_2) \qquad \text{.........1}$$

where

M_C = the discounted costs per km of the measures adopted to provide a serviceable road over time "t";

VOC_1 = the discounted vehicle operating costs per km on the road over time "t" without the measures;

VOC_2 = the discounted vehicle operating costs per km on the road over time "t" with the measures.

The question to be answered is what practical measures can be taken by DOR to reduce the effects of pavement deterioration and provide a ***reasonable*** level of service to the road user at a minimum life-cycle cost? Or, in terms of equation 1, how can DOR minimise (VOC_2) and therefore maximise vehicle operating cost savings (VOC_1-VOC_2), while minimising the costs (M_C) to Government? The answer to this question represents the pavement management strategy for the Department and will comprise an optimal mix and timing of reconstruction, rehabilitation and ***planned maintenance*** activities on the Strategic Road Network.

In section 2, this Discussion Paper looks at the deterioration process of paved and unpaved roads and provides information on a practical means of defining and measuring pavement condition in Nepal. Paved roads are costly to construct but as we shall see, they offer more scope for management intervention to retain serviceability than unpaved roads. This Paper is therefore principally concerned with bitumen roads and section 3 examines possible strategies for use by the Department in managing the 2,676 km of these roads in the Strategic Network. Section 4 reaches a provisional conclusion regarding a pavement management strategy to suit the present conditions in Nepal and is intended to encourage further discussion on this subject.

2. PAVEMENT DETERIORATION AND CONDITION PARAMETERS

The starting point of pavement management is to understand the characteristics of pavement deterioration and to determine a means of describing and measuring, as objectively as possible, the condition of the pavement. We shall then be in a position to define the nature and extent of the problem we have to address.

2.1 Deterioration Characteristics

As stated in section 1 all road pavements deteriorate over time. However, the deterioration characteristics of unpaved (earth/gravel) and paved (bitumen) roads follow a very different pattern and therefore require a different approach to their management. They are described under the separate headings below. Nevertheless. it is most important to remember that for unpaved and paved roads alike:

the application of routine drainage maintenance (cleaning out drains, culverts, bridges; repair of scour damage, scour controls and drainage structures; vegetation control) is a prerequisite for all other pavement management actions.

In the discussions on pavement deterioration and management that follow, it is assumed that a basic level of routine drainage maintenance is on-going on *all* roads.

Unpaved Roads

With unpaved roads the deterioration path is both linear and rapid and offers little choice in the selection of management options. If maintenance is deferred, the consequences become immediately apparent; the pavement deteriorates at a fairly uniform rate until very high levels of roughness are reached and pavement failure occurs. The action of traffic causes corrugations and rutting and when combined with rainfall, creates deeper ruts, potholes, gullies and washouts. In dry weather, the bond within the surface material is weakened resulting in the loss of fine material as dust and the eventual disintegration of the pavement.

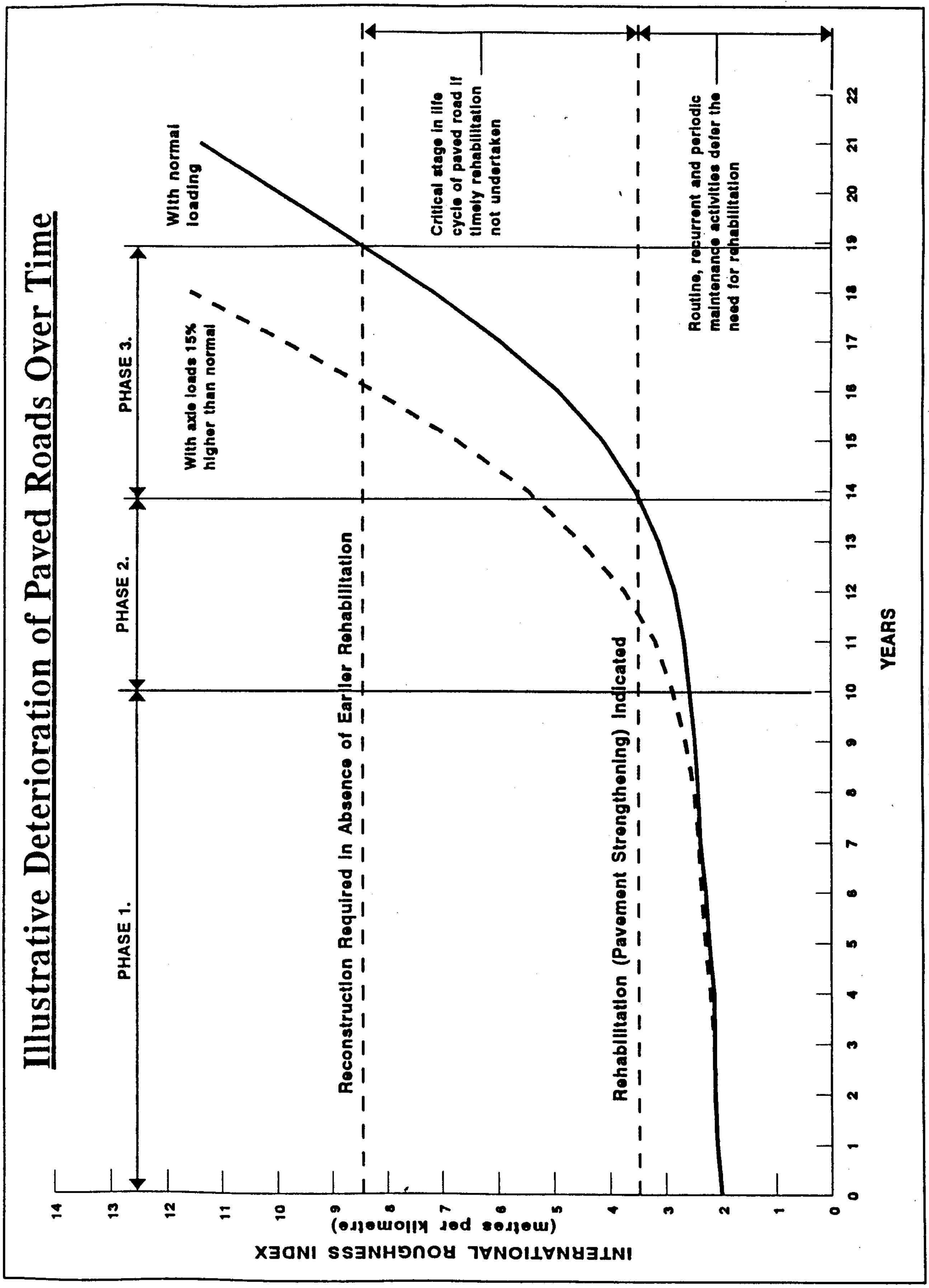
Surface roughness, the main factor affecting vehicle operating costs and hence serviceability, is controlled by grading the pavement surface and particular attention should be given to this activity. Additionally, regravelling will be needed to replace surface material lost from gravel roads. If the road is allowed to disintegrate, reconstruction will be required to restore serviceability for the road user. With routine drainage maintenance only, unpaved roads in Nepal are unlikely to remain serviceable for more than 3 years (two monsoons).

Paved Roads

The progression of deterioration of paved roads with minimal maintenance follows a distinctly non-linear path which approximates to the curve shown in Figure 2.1 overleaf. From the curve, it can be seen that deterioration essentially passes through three phases.

Phase 1 - can extend to two-thirds the life of the road and is a period of limited visible deterioration with good serviceability and a marginal increase in roughness. Pavements in this phase can be considered in ***good*** condition and deterioration, where apparent, is usually limited to minor cracking, the occasional pothole and edge damage.

Figure 2.1



Note: Data are based on the following assumptions: asphalt cone pavement (SNC=3.5); ADT=2500; rainfall=120mm/m; routine drainage maintenance plus minimal extra maintenance. Graph developed from Fig 2.1, World Bank Policy Study, "Road Deterioration In Developing Countries", 1988.

Phase 2 - visible deterioration now apparent and increasing markedly towards the end of the phase with a noticeable rise in the level of roughness; serviceability varying from reasonable to poor. Pavements in this phase can be considered in ***fair*** to ***poor*** condition and deterioration is characterised by extensive cracking, potholes, wheeltrack rutting, edge and shoulder damage.

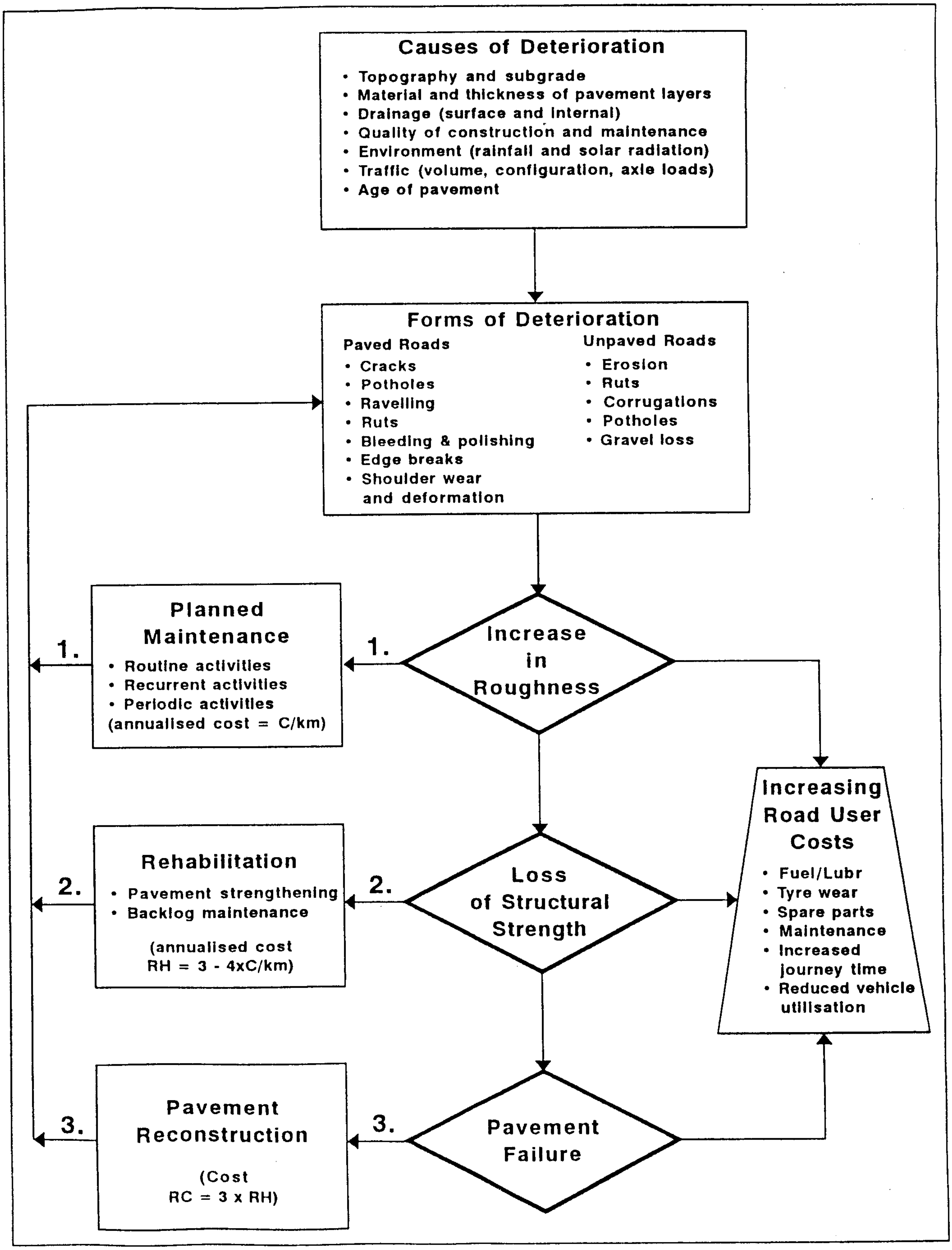
Phase 3 - is the critical stage in the life of the pavement represented .by increasingly rapid deterioration leading to radical structural failure of the pavement. Roughness reaches unacceptable levels during this phase resulting in minimal and, ultimately, total loss of serviceability. Pavements in this condition are no longer able to carry their design loads and can be considered in ***very poor*** to ***failed*** condition.

During Phase 1, the road can be kept in a serviceable (good/fair) condition with routine and recurrent maintenance activities alone (remember that routine drainage activities are essential for any management approach).
Phase 2 is reached when deterioration has advanced to the point where periodic maintenance (resealing) is needed. At this point, resealing and continued routine/recurrent maintenance activities will extend the life of the road and keep the pavement in a good to fair condition until such time as traffic loading and the age of the road results in a need for strengthening (structural overlay). This is the start of Phase 3 and the application of a structural overlay will reduce roughness to new pavement levels and increase pavement strength to meet traffic requirements for many more years. A new pavement cycle therefore begins which effectively returns us to the starting point of Phase 1. Provided adequate routine, recurrent and periodic maintenance activities are undertaken, a paved road should rarely require costly reconstruction.

However, if maintenance is deferred, the pavement passes relatively quickly from Phase 1 to Phase 2 with decreasing serviceability and a major reduction in the life of the road. Axle loads above the design level will have a similar effect. If strengthening is then omitted, Phase 3 is reached and reconstruction is inevitable. It is interesting to note that in Nepal where, generally, maintenance has been minimal and even routine drainage maintenance has been neglected, the time to Phase 3 is, on average, only 6 to 7 years. Compare this time with the period of some 14 years shown in Figure 2.1. Even allowing for the more extreme climate and environmental conditions, something is clearly wrong with the present management of road pavements in Nepal.

A Flow Chart of pavement deterioration and treatment cycles is given in Figure 2.2 overleaf which emphasises the points made above. Unlike unpaved roads,

Figure 2.2 - Road Pavement Deterioration and Treatment Cycles



there is considerable scope for managing paved roads within and by application of the treatment cycles shown. This is examined in Section 3.

2.2 Definition and Measurement of Pavement Condition

Before we can implement a pavement management approach, we must have some means of defining and measuring pavement condition which takes account of the deterioration characteristics noted in section 2.1. There are essentially four primary measures of pavement condition:

i) **surface roughness ;**

ii) **surface distress;**

iii) **structural capacity;**

iv) **pavement texture (friction).**

Variations are possible in these measures depending on the stage of development of the network, the importance of the particular road under consideration and hence, the level of management information required. However, all the measures have a common objective which is to provide a means of determining how well the pavement is performing and meeting the serviceability requirements of the road. A brief description of the measures and the way in which they are being introduced by DOR is set-out under the headings below.

<u>Surface Roughness</u>
Of all the measures of pavement condition, roughness of the pavement surface is probably of the greatest concern to the road user. As the pavement deteriorates, the surface becomes rougher and less serviceable and results in an increase in vehicle operating costs. Relationships have been established between pavement roughness and the cost of operating vehicles on the pavement, and these relationships have been incorporated into a Vehicle Operating Cost Model specific to Nepal which is available in the Planning Branch.

Various systems are available for measuring roughness ranging from the more sophisticated laser profilometers to the relatively inexpensive response type instruments. However, regardless of the type of system, the International Roughness Index (IRI) in metres/km is used to provide a common scale for recording roughness measurements. The DOR Planning Branch has been conducting annual roughness surveys of the Strategic Network from fiscal year 1992/93 and the information is held on the HMIS central database. The Planning Branch uses a vehicle mounted Bump Integrator which is a response type instrument for this task and details of the instrument, its calibration and the method of conducting road roughness surveys are given in Annex I.

The principal use of roughness is for determining the cost of operating vehicles on the road. It can also be used by the Department to provide an indication of the need for rehabilitation and reconstruction. However, care must be exercised in the use of roughness alone for determining pavement condition ***as the measurement is not absolute but must be related to the type of pavement construction***, especially the surfacing. An example of deterioration in terms of roughness for an asphaltic concrete pavement is shown in Figure 2.1. For surface dressing on a crushed gravel base the shape of the curve would be similar but the starting point would be an IRI value of 3.1, rehabilitation would be indicated around an IRI of 7.9 and reconstruction at an IRI of 13 upwards.

Surface Distress

Surface distress is of particular importance to maintenance engineers as it provides the first visual indication of pavement deterioration and should trigger some form of remedial action. The characteristics vary between unpaved and paved roads as shown in the following table.

Distress Characteristics	Unpaved Roads	Paved Roads
Stripping/bleeding/ravelling	No	Yes
Cracking (longitudinal, transverse, alligator and block)	No	Yes
Edge damage	No	Yes
Shoulder step	No	Yes
Camber loss	Yes	No
Rutting	Yes	Yes
Corrugations	Yes	No
Potholes	Yes	Yes
Gravel loss	Yes	No

Although fully automated equipment is now available for gathering distress information, this can only be justified for large and extensively trafficked networks which is not the present case in Nepal. The normal approach is to quantify some or all of the surface distress characteristics by means of a visual examination. The results are then combined into a numerical index, say from 0 = good to 5 = poor. This is the approach adopted by the DOR Planning

Branch for conducting annual distress surveys of the Strategic Network since fiscal year 1992/93 and is described in detail in Annex 2.

Surface distress measurements are useful for providing intervention levels for maintenance activities, in particular, for indicating the timely need for resealing. Used independently or in conjunction with roughness, distress measurements can provide the Department with an objective assessment of the condition of the Strategic Network.

Structural Capacity

The structural capacity of a pavement is the measure of a pavement's ability to carry the design loading. As commercial traffic loads are applied, the pavement becomes progressively weaker until strengthening is carried out or failure occurs. Surface distress and roughness are often, but not necessarily, an indication of reduced structural capacity and a more accurate means of measuring pavement strength is required.

The Structural Number (SN) which is related to the California Bearing Ratio (CBR) and the thickness of the individual pavement layers, and pavement deflection are the normal measures of pavement strength with the SN being the most statistically significant. However, this is a complex subject and cannot be dealt with fully in this paper. Non-destructive testing incorporating deflection measurements is the most common technique used to assist in evaluating the structural capacity of a pavement. Deflection measurements can be related empirically to future performance and total life expectancy and a relationship exists between deflection and Structural Number (SN).

Automated equipment such as the Deflectograph and Falling Weight Deflectometer are available for taking pavement deflection measurements. However, the equipment is costly and produces very large amounts of data for processing, it is therefore better suited for large and heavily trafficked networks. The Benkleman Beam is a relatively inexpensive and easy to apply item of equipment for measuring deflection although it is slow in operation. Used in conjunction with the Dynamic Cone Penetrometer for determining insitu CBR values of the pavement layers, it is a practical tool for measuring the structural capacity of a pavement at the project level and is the normal approach adopted by the Department for the design of structural overlays.

Pavement Texture

The measurement of pavement texture or friction is principally concerned with safety on paved roads. Under the action of traffic and climate, the road surface loses its texture resulting in reduced skid resistance especially in wet conditions. A measure of pavement friction is therefore necessary to provide an indication of hazardous conditions for traffic so that remedial action, usually in the form of resealing, can be taken.

The ability of a pavement to provide skid resistance is measured in terms of a Sideways Force Coefficient (SFC) and Sensor Measured Texture Depth (SMTD). The SFC is concerned with the effect of micro texture and the SMTD with coarse or macro texture of the pavement surface. The SMTD is of particular importance for high-speed roads. As in the case of structural capacity, the assessment of skid resistance is a complex subject and cannot be dealt with in this paper. Equipment is available for measuring the SFC and SMTD but it is costly to purchase and operate.

For the time being in Nepal, it is probably sufficient to ensure that aggregates with a high polished stone value are used in the wearing course, that resealing of a good standard is undertaken in a timely manner, and that adequate camber is provided. Particular attention should be paid to hazard sections such as bends and junctions and through settlement areas.

3. PAVEMENT MANAGEMENT

Sound pavement management involves ***response management*** in dealing with emergencies and ***management for control*** to make the best use of available resources. The fundamental difference between response and control is that management for control involves planning and the use of reliable information. Given the absence of reliable information on the road network in the past, it is probably true to say that DOR has previously adopted a mainly responsive approach to management of the road network. This has resulted in a lower level of service to the road user and reduced output efficiency from the human and financial resources available to the Department.

The necessary introduction of control management principles to pavement management should enable the following questions to be answered:

- <u>What</u> actions need to be taken for a particular stretch of pavement?
- <u>When</u> is action needed in order to maintain the serviceability of the road, prevent failure and extend the pavement life?
- <u>Where</u> and in what order should the pavement actions be implemented?
- <u>How</u> should the actions be carried out given a wide range of potential materials and implementation techniques?

- Who will be responsible for managing and implementing the actions to preserve the pavement?

A pavement management system is no more and no less than the formal establishment of co-ordinated processes for determining the answers to these questions. These processes should be combined with feedback on the results of the ensuing pavement activities and consequent adjustment and refinement of the activities. Pavement management systems can therefore be as complicated or as elementary as we wish to make them, however, it must never be forgotten that:

The overriding aim of pavement management and any related system is to ensure that timely and appropriate action is undertaken on the roads and care must therefore be taken to ensure that the system does not become an end in itself.

The objective of this paper is not to examine pavement management systems in detail but to focus on the principles of pavement management. Once these are understood, appropriate systems can be developed within DOR to suit the Department's particular requirements. Pavement management principles are examined under three sub-headings:

i) Strategy and Approach

ii) Management Levels

iii) Management Information.

3.1 Strategy and Approach

Pavement Management Strategies

When a road has been constructed, there are essentially three broad strategies open to the Department for managing the pavement:

i) The application of planned maintenance comprising interdependent routine, recurrent and periodic maintenance activities. By deferring the need for the more costly activities of rehabilitation and reconstruction and by keeping vehicle operating costs to a minimum, planned maintenance can be considered the optimal strategy in purely economic terms. However, this strategy can only be applied effectively to roads in a maintainable (good/fair, SDI = 0-3.0) condition

ii) The provision of minimal ad-hoc routine and recurrent maintenance activities followed by rehabilitation of the pavement when it reaches a poor condition. As the annualised cost of rehabilitation is three to four times the cost of the foregone maintenance, this is clearly not a cost effective strategy. Moreover, no account is taken in this calculation of the higher vehicle operating costs due to the resulting increase in pavement roughness.

iii) The provision of minimal routine and recurrent maintenance activities only until such time as the road becomes totally unserviceable and full pavement reconstruction is necessary. As the cost of reconstruction is three times the cost of rehabilitation, this strategy is extremely costly for all roads with the exception of those with minimal traffic. Applying this strategy effectively amounts to a policy of disinvestment in the road network.

These strategies are indicated in the Pavement Deterioration Flow Chart, Figure 2.2. In considering the strategies, it should not be forgotten that routine drainage maintenance is a prerequisite for all other maintenance actions (section 2.1). Also, that planned maintenance can only be carried out on roads in a maintainable state ie in good/fair condition and poor roads will need reconstructing or rehabilitating before strategy (i) can be applied to them.

Each strategy involves a cost to the Government and the road user and, as we have seen in section 1, the aim of pavement management is to keep these costs and the cost of road construction to a minimum. To this end, the strategy of planned maintenance will, in most cases, produce the optimum result. However, given the present limits on DOR capacity and maintenance funding, it is clear that the Department cannot implement planned maintenance on the whole of the Strategic Network. While the aim of DOR should be to move from the present application of Strategy (ii) to Strategy (i), this will be a gradual process. A start must therefore be made on establishing road priorities for planned maintenance for which a ***global*** rather than a project approach to pavement management and the road network is essential.

<u>Pavement Management Approach</u>

There are two basic approaches that can be taken when applying a pavement management strategy comprising planned maintenance:

i) **The Cyclic Approach** - in which pavement actions are undertaken at fixed intervals on any particular stretch of road. This approach comprises a relatively straightforward management exercise with predictable workload and funding but often produces a less than optimal (but still economic) result. It is therefore better suited to roads where the principle agents of pavement deterioration are climate and the environment rather than traffic.

ii) **The Intervention Approach** - where pavement actions are taken, as far as possible, in direct response to preset levels of pavement deterioration. The application of an intervention approach is a difficult management exercise and produces a variable annual workload and, consequently, variable resource and funding needs. Moreover, for effective planning using this approach, a comprehensive database of pavement performance over time is essential in order to determine historical trends. On the other hand, optimal results can be obtained in terms of road serviceability and cost savings especially where higher traffic levels (above 5,000 ADT) are the norm.

The Cyclic Approach is the preferable approach to planned maintenance for Nepal at the present time. In applying this approach, the principle to be adopted is that maintenance actions implemented a few months early are still economic while those applied half-a-day late are ineffective and therefore a poor use of funds. However, regardless of the approach adopted, it is essential that regular feedback is obtained on the efficacy of the maintenance actions so that any necessary adjustment of the actions can be made.

The cyclic approach to the organisation of routine and recurrent maintenance involves the following procedures.

- **Establish Control Sections** - divide the road network in a Division into sections which can be managed by one overseer (Naike) taking account of environment, topography and traffic levels. These sections will generally be from 20 km to 35 km in length.
- **Define Activities** - assess the type and extent of the routine and periodic maintenance activities needed on each control section.
- **Allocate Resources** - determine the method of implementation and the resources needed to undertake the activities on each control section.
- **Optimise Resources** - review and optimise the resources needed to cover the activities on all the control sections in the Division.
- **Prioritise the Control Sections** - set priorities based on strategic importance and level of traffic and then establish priorities for the maintenance activities on each control section.

These procedures should lead to the production of an annual cyclic maintenance programme in each Division including work and resource schedules. The cyclic programme will cover the full year and must be supplemented in most cases with provision for responsive measures to be taken during the four month monsoon period. By means of feedback from the field, the programme is adjusted in successive years until an optimal result in terms of cost and pavement deterioration is obtained. Priorities on control sections and maintenance activities are applied when there is a budget deficit always remembering that routine drainage maintenance is a prerequisite for other maintenance actions on a particular control section.

The Cyclic Approach to the organisation of periodic maintenance varies between gravel and bitumen surfaced roads. For gravel roads, periodic maintenance is limited to reshaping and regravelling the road pavement at fixed intervals which. in Nepal, will be every three to four years. For bitumen roads, the recommended action is to apply a non-structural seal coat at fixed intervals of about five to six years in the Hills and six to seven years in the Terai. The seal coat is designed to renew the water-proofing properties of the pavement surface and can consist of single or double seal surface dressing, a slurry seal, or a cape seal. the use of surface dressing is generally to be preferred for improving skid resistance.

Cyclic resealing, combined with routine drainage maintenance, is considered the single most cost effective means of improving the serviceability of the Strategic Road Network. It is a straightforward management exercise, has predictable levels of funding and provides a means of encouraging the development of local contractors. If the resealing intervals suggested above are applied to the present length of bitumen roads in the Strategic Network, the result will be a programme of some 400 km to 500 km of resealing annually. However, in order to realise the potential benefits from resealing, the work must be carried out to a reasonable and uniform quality. This will require new specifications and improved supervision and workmanship. It is a primary role of the RMRP and the Resealing Component of the RMP to assist DOR in achieving these improvements.

3.2 Management Levels

There are essentially three interdependent management levels in DOR at which pavement management should be applied:

i) Network Level,

ii) Operations Level and

iii) Project Level.

These are examined separately below.

<u>Network Level</u>

Effective pavement management starts at Network Level. At this level, pavement management is the responsibility of the DOR Planning Branch and the emphasis is placed on medium-term planning and global management of the Strategic Network. The first job of the Planning Branch is to allocate priorities to the roads in the Network. These should be based on strategic importance and traffic levels and should ideally be related to a National Development Plan prepared by the NPC and a Transport Investment Plan which is the responsibility of MOWT.

If the best use is to be made of the available resources, the level of pavement treatment should not be uniform across the Network but must be related to the level of service required. The setting of road priorities therefore provides the basis for establishing a medium-term Road Investment Plan. This Plan will take the form of 3 year and 5 year rolling programmes of reconstruction and rehabilitation, together with a global resealing programme for bitumen roads. Additionally, the Planning Branch should monitor, annually, the overall condition of the Strategic Network and the level of service provided to the road user. A strong and dependable Planning Branch is essential for providing these Network Level pavement management functions.

Operations Level

Pavement management at Operations Level is the responsibility of the DOR Maintenance Branch and is principally concerned with the detailed planning and implementation of maintenance activities in the field. The Maintenance Branch staff in DOR Headquarters have an overall co-ordination and supervisory role while the Regions and Divisions are responsible for the day-to-day planning, organisation and implementation of maintenance activities in their particular areas.

The Regions should be directly responsible to the DDG Maintenance for the performance of their Divisions. They should prepare annual programmes for regravelling unsurfaced roads and, as soon as a local capacity for resealing work has been developed, the Regions should also take-over responsibility for the preparation of cyclic resealing programmes on bitumen roads from the Planning Branch. In general, these programmes will be based on the road priorities established by the Planning Branch.

The Divisions have the major task of transforming the broad planning process undertaken by the Planning Branch and the Regions into action. The role of the Divisions is to ensure that an ***appropriate*** level of service is provided by the Network to the road user and to achieve this, division staff need an intimate knowledge of the roads in their Division and the traffic on these roads. With this information and the agreed road priorities, it is the job of the Divisions to undertake the detailed management and implementation of backlog, ad-hoc and planned maintenance activities. The resulting work programmes should be in keeping with the capacity of the Division and make the best use of the resources available to the Division.

Project Level

For the time being, reconstruction and rehabilitation of sections of the Strategic Network will be carried out by DOR as projects. Pavement management at Project Level is therefore concerned with the feasibility, detailed design, and implementation of projects initially identified by the Planning Branch and included in the Network Level 3-year rolling programme. These potential projects are then passed to the DOR Foreign Co-operation Branch or the Design Branch depending on the extent of the work to be undertaken.

The Foreign Co-operation Branch will be responsible for large projects requiring donor support and, hence, the use of international consultants. It is the job of the Foreign Co-operation Branch to procure the necessary donor support, appoint consultants, award contracts and oversee the project as a whole.

A similar approach is taken for smaller projects which will be funded by HMG/N. However, these projects will be assigned to the Design Branch and the work will generally be undertaken using local consultants.

3.3 Management Information

As previously noted, management for control is an essential feature of pavement management and requires reliable data on which objective decisions can be made and implemented. In the case of pavement management for the Strategic Network in Nepal we need to have data covering five elements:

- the inventories of the roads comprising the network;
- the pavement deterioration process and a means of defining and measuring it in the field;
- traffic levels and composition on the roads comprising the network;
- the relative costs of reconstruction, rehabilitation and planned maintenance activities on the network (Road Agency costs);
- the costs to road users of using the network (vehicle operating costs).

A comprehensive and reliable database from which management information can be generated is, therefore, an essential requirement for introducing the necessary control element into the DOR's pavement management operations.

As data is expensive to collect, process and store, the data obtained for pavement management should be appropriate to the decisions that need to be made ***and can be acted on***. The data requirement will therefore vary with the management level (Network, Operations or Project), and the importance of the road. Given the present limitations on management and the relatively early development and low utilisation of the Strategic Network, extensive and sophisticated data collection cannot be justified at this time in DOR. The recommended data should therefore generally conform to Information Quality Levels III and IV given in the World Bank Technical Paper, "Information Systems for Road Management: Draft Guidelines on System Design and Data Issues".

Brief notes on the data needed to support the DOR management activities described in section 3.2 are given as follows.

Network Level Data - should comprise Quality Level IV data relating to the whole of the Strategic Network. The data will cover the five elements noted above and should be adequate for prioritising the roads in the Network and for the preliminary identification and costing of road sections for reconstruction and rehabilitation. The data should also support the preparation of national level statistics on the extent, performance and trends of the Strategic Network in meeting Nepal's road transport needs. It should be noted that the Network Level data for DOR will generally be unsuitable for use in the more sophisticated economic models such as HDM III.

Operations Level Data - will vary to suit the needs of the Regions and the Divisions. The Divisions will require specific data comprising road inventory, work outputs, maintenance costs and a detailed knowledge of local problem areas to enable them to prepare work schedules and budgets for routine and recurrent maintenance activities. The collection of this data is the responsibility of the Divisions. The Divisions will also be allocated automatic traffic loggers by the Planning Branch for installing at key locations on the Network. It will be the responsibility of the Divisions to maintain the loggers and record and send the data to the Regions for onward transmission to the Planning Branch. The Regions will hold the road inventories and work schedules supplied by the Divisions, together with budget details, in order to monitor progress. In addition, the Regions will receive pavement condition and traffic information from the Planning Branch to assist them with planning and control.

Project Level Data - should assist management with the detailed assessment, prioritisation and design of road sections identified at Network Level for reconstruction and rehabilitation. The required data is therefore of a high quality (Level II/III) but is limited to relatively short lengths of the Strategic

Network. It will comprise a detailed road inventory; traffic levels, classification and axle loads; pavement condition, including structural capacity; and costs; all of sufficient accuracy to secure the necessary funding and to prepare contract bid documents. While use can be made of existing Network and Operations Level Data, this will necessarily be limited and supplementary data of the required quality will have to be specifically acquired by the project consultants. Project Level data is normally suitable for use in economic models.

Data guidelines for each DOR management level, including recommended collection and updating periods and responsibility for the data, are given in Annex III.

The DOR has installed in the Planning Branch, and is continuing to develop, a Highway Management Information System (HMIS) which is now capable of providing Network Level data/information for each of the five data elements. Although still at an early stage, the HMIS will support a basic level of pavement management on the Strategic Network and the aim of the Department is to progress the introduction of management systems for control at the Network (Planning Branch) and Operations (Region and Division) Levels. Examples of Network Level information produced from the HMIS, and which can be used in pavement management, are given in Annex IV.

4. CONCLUSIONS

When introducing and implementing effective pavement management in DOR on the Strategic Network, the following important conclusions can be drawn.

i) Given the high cost of maintenance and the relatively low utilisation of roads in Nepal, the aim of DOR should be to provide a ***reasonable*** level of service to the road user based on the strategic importance of the road and the level of traffic using the road. Maintenance standards will therefore not be uniform for each road but will vary throughout the Strategic Network.

ii) In order to provide effective pavement management, the DOR must move from response management to management for control. The difference is that for control management, planning and hence the use of reliable information for objective management decisions, are introduced.

iii) There is no mystery about pavement management and pavement management systems. They comprise normal management principles and can be as complicated or elementary as <u>we</u> wish to make them. For the present Strategic Network, an uncomplicated approach to pavement management will produce the desired result and so-called proprietary systems are unnecessary.

iv) Routine drainage maintenance (cleaning out drains, culverts, bridge openings; repair of scour damage, scour controls and drainage structures; vegetation control) is a prerequisite for all other pavement management actions.

v) If the best use is to be made of available resources (as indeed it must), planned maintenance comprising interdependent routine, recurrent and periodic activities should be introduced with priority being given to the more highly trafficked roads. However, planned maintenance can only be implemented on roads in a maintainable condition (SDI 0-3.0).

vi) At present traffic levels, the cyclic approach to planned maintenance (undertaking the maintenance activities at fixed intervals) is the preferred approach for DOR.

vii) The periodic maintenance of bitumen roads should comprise cyclic resealing at intervals of 5-6 years in the Hills and 6-7 years in the Terai.

viii) Pavement management should be applied interactively at three levels in DOR: Network Level (Planning Branch), Operations Level (Regions/Divisions), Project Level (Foreign Co-operation Branch/Design Branch). Effective management will require close interaction and an exchange of data and information between all three levels.

The importance of routine drainage maintenance (conclusion v), especially in the Hills, cannot be overstressed. If this work is neglected, pavement management in any form does not exist.

THE MEASUREMENT OF ROAD ROUGHNESS

Introduction

Road Roughness is defined as "the deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality, dynamic pavement loads and pavement drainage". (ASTM E867-87)

The roughness of a road surface is an important measure of road condition when related to the type of pavement construction, and it is a key factor in determining vehicle operating costs (VOC). Roughness increases the wear on vehicle parts and rolling resistance and has an appreciable impact on VOC and the safety, comfort and speed of travel.

Roughness Measuring Devices

Reliable measurement of road roughness is therefore an important activity in pavement management. For this purpose, a variety of roughness measuring devices have been developed and these can be grouped into three different class as given in the Transport Research Laboratory (TRL) Research Report 301.

- The simplest in concept are the static road profile measuring devices such as rod and level, which measure surface undulations at regular intervals.
- The second type of instrument is the dynamic profile measuring device such as TRL high-speed profilometer.
- The third type of instrument is the response type road roughness measuring device. The standard device (fifth wheel towed Bump Integrator, BI) and non- standard device (vehicle mounted Bump Integrator). These instruments measure the cumulative vertical movements of a wheel or axle with respect to the chassis of a vehicle as it travels along the road.

The response measurement is used directly as a roughness index in a standard device. Whereas using a non-standard device, the response is converted to a standard roughness measure by calibration.

Two types of instrument are in use by DOR:

i) The MERLIN Roughness Machine

ii) The Vehicle Mounted Bump Integrator

The MERLIN Roughness Machine - is a Machine for Evaluating Roughness using Low cost Instrumentation (see fig a, page 5). The device was designed by the Transport Research Laboratory (TRL), UK, and can be used either for direct measurement or for calibrating non-standard response type instruments such as the vehicle mounted Bump Integrator. It can be locally manufactured, is relatively cheap to produce and is wheeled along the road to measure surface undulations at regular intervals.

<u>The Vehicle Mounted Bump Integrator (VMBI)</u> - consists of essentially three components: a vehicle, a Bump Integrator (BI) unit and a display counter which is connected electrically to the BI unit (see fig b, page 5). The BI unit is fixed to the rear floor of the vehicle and is connected to the differential by means of a special cable and attached hook. The measurement obtained represents the response of the vehicle to the road surface and is recorded on the display counter in inches. Thus, the measurement is a function of the instrument, the operating procedure, the vehicle and all of the variables affecting its response (such as weight, tyre balance, shock absorbers, tyre pressure etc.). ***Therefore, the instrument has to be calibrated to a standard reference to ensure that the results obtained are consistent with the standardized values.***

The VMBI reading is converted to a unit roughness value in terms of mm/km using the following relationship:

$$Roughness\ value\ (mm/km) = \frac{actual\ count\ x\ 25.4}{length\ of\ the\ section\ (kilometres)}$$

For network surveys, this instrument is suited for roughness measurement under Nepal conditions covering 100-150 km of continuous survey a day. However the mechanical properties of the vehicle must be kept constant through good maintenance and operating practices. While measuring the roughness the tyre pressure of the vehicle and the pay load of the vehicle should be the same as at the time of calibration. Changes in the tyre pressure and the vehicle weight can have a material effect on the measured roughness value. The scale widely adopted for roughness measurements these days is the International Roughness Index (IRI). This scale is derived from the road profile data by a fairly complex mathematical procedure and represents the vertical movement of a wheel with respect to the chassis in an idealised suspension system. Roughness using the VMBI is measured in terms of units of vertical movement of the wheel per unit length of road, and is produced in BI (mm/km). BI is then converted to IRI (m/km) using the following relationship :

$$IRI = 0.0032\ (BI\ mm/km)^{0.89}$$

$$BI = \left(\frac{IRI}{.0032}\right)^{1.124}$$

Method of Calibration

The Department of Roads has been using the MERLIN for calibrating vehicle mounted bump integrators. The calibration is done by determining with the MERLIN the true profile, and hence the standardised roughness (IRI), of test sections of road covering a range of roughness values. Generally 10 test sections are selected for this purpose. The VMBI is then used to measure the same test sections from which a relationship with the MERLIN values can be determined

As an example, test sections used for calibrating roughness during fiscal year 94/95 are shown in the following Table.

Test Section	Length (m)	Avg Merlin reading (mm)	Avg VMBI (L R 60-0-1) Reading (ins)	Calculated BI (mm/km)
Naubise	433	39.5	70.0	1785
Dhumbarahi	433	89.3	130.5	3256
Dakshinkali	433	149.8	253.5	6103
Satdobato	433	136.9	225.4	5519
Sano Thimi	433	163.6	256.1	6789
Vanasthali	433	40.0	61.7	917
Thimi	433	161.3	188.8	6676
Nagarkot	433	163.0	242.2	6760
Godavari	433	95.3	137.6	3541
Banepa	433	156.6	247.5	5257

Prior to the use of the MERLIN, the mechanical amplification of the arm is checked by using a small calibrating block (6 mm thick). Insertion of the block under the probe should move the pointer by 60 mm.

The MERLIN is run along each wheel path of the BI vehicle taking 200 measurements at an interval of each wheel revolution. At each measuring point, the machine is rested on the road with the wheel in its normal position and the rear foot, probe, and stabiliser in contact with the road surface. The position of the pointer on the chart is recorded with a cross (x) in the appropriate column and, in order to keep a record of the total number of observations, a cross is also made in the '***tally box***' on the chart. The handle of the MERLIN is then raised so that only the wheel remains in contact with the road surface and the machine is moved forward to the next measuring point and the process repeated. A typical completed chart is given as an example on page 6.

When 200 observations have been made, the chart in removed from the MERLIN. The positions mid-way between the tenth and the eleventh crosses, counting in from each end of the distribution, are marked on the chart below the column boundaries. The Spacing between the two marks, D, measured in millimetres is the roughness index on the MERLIN scale. This process is repeated twice in each wheel path, the second time by shifting the initial point by half a revolution of the wheel and the measuring is done as before at each revolution interval. Four observations are therefore taken in every test section, ie 2 readings in each wheel path of the vehicle.

After completion of the MERLIN work, the VMBI is run for at least 10 times over the selected test sections to obtain a uniform result, an example is given on page

7. Using this data the relationship between the MERLIN results and the VMBI is established by regression analysis.

Method of Roughness Measurement

The Department of Roads is using the non-standard VMBI for undertaking roughness measurements and providing the necessary calibration of the instrument by means of the MERLIN as described above. The vehicle mounted BI is being used because it is inexpensive to purchase and operate, relatively maintenance free and can meet the present needs of the Department for a condition rating of the Strategic Network. The DOR has been carrying out annual roughness measurements on the Strategic Network since fiscal year 1992/93.

In 1992/93 measurements were taken in both directions on some important highways. However, the variation in the results for single and both directions was found to be small (about 10%). All subsequent measurements have therefore been taken in one direction only.

Roughness is measured in the field with the VMBI by driving the vehicle over the road surface to be measured. Prior to taking measurements, the vehicle is warmed by running 5-10 km and tyre pressures are adjusted. The tyre pressure not only affects the roughness value but also affects the value of the distance measuring equipment (the Halda Rally Computer). The speed of the vehicle is maintained at about 32 km/hr wherever possible. It is possible to survey 80/km of road per day under favourable conditions.

The Strategic Road Network has been divided into links varying in length between 142 metres and 42 km. Each link has defined node points and has been given a unique reference number. Roughness measurements always commence and finish at a link node point on the particular road. The roughness is normally recorded at intervals of 1 km but, since roughness values are relative to the type of pavement, this interval is adjusted to suit changes in pavement construction. Distances are recorded using a Halda Rally Computer fitted in the vehicle. The instrument is calibrated by comparing the reading over a precisely measured test section.

Field data is recorded on a standard sheet (see example on page 8) and is then entered into a micro computer based spreadsheet. The spreadsheet automatically calculates the data in the given format and provides roughness values in BI (mm/km) and in IRI (m/km) which are then input into the HMIS. Roughness data in the HMIS is averaged over specified road sections and output in the form of a histogram. A comparison of roughness progression over time is then possible (see example in Annex IV).

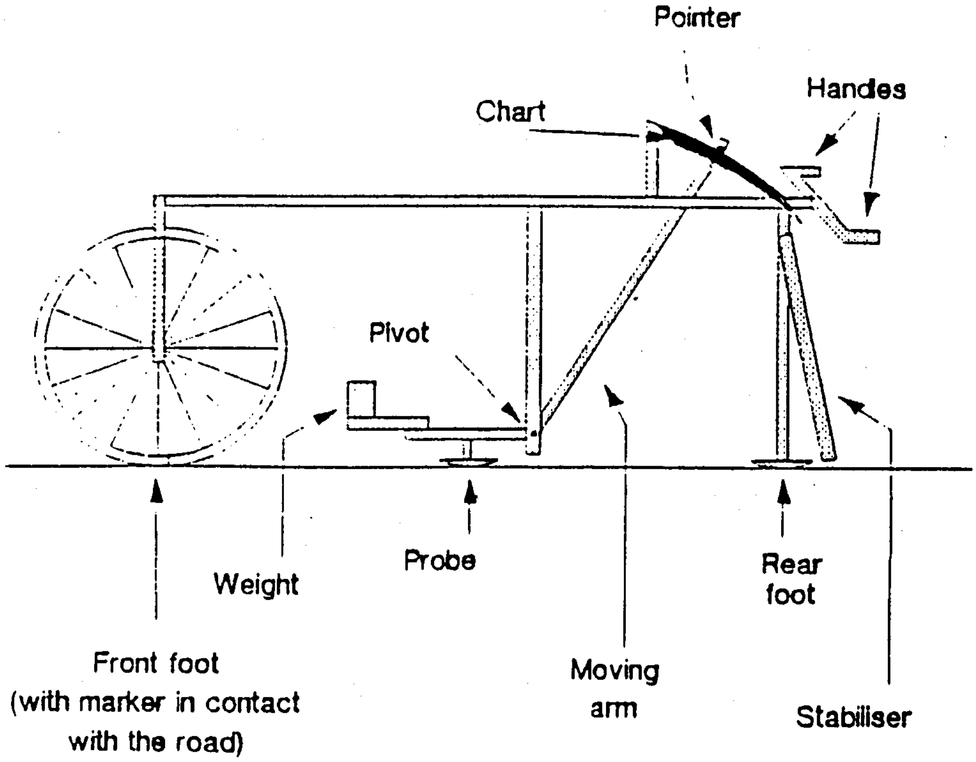


Figure a. Sketch of the Merlin

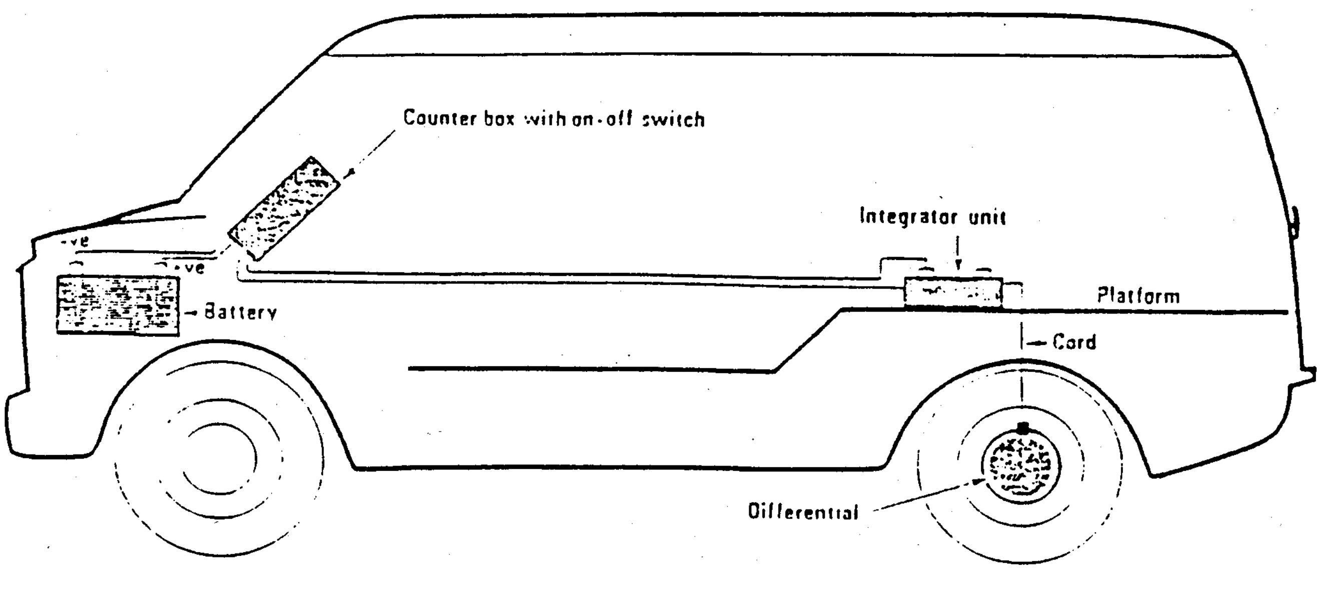


Figure b. Sketch of Vehicle mounted Bump Integrator

MERLIN DATA

TEST SECTION: Banepa

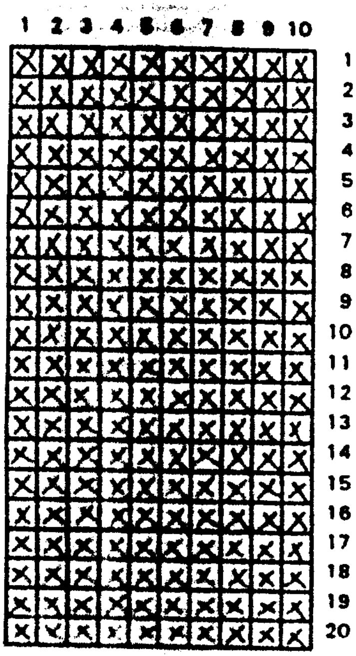
WHEEL PATH: Left

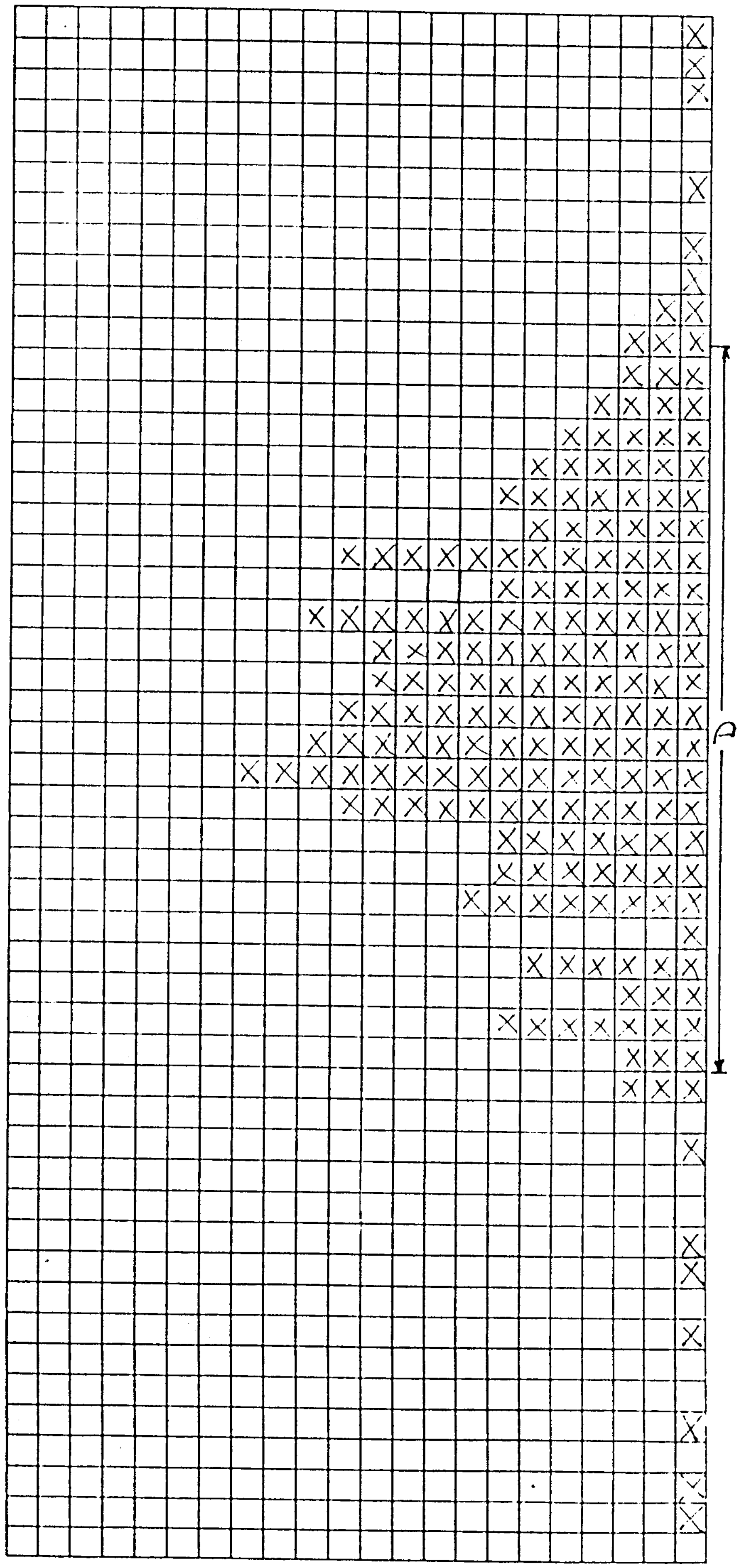
DATE: 4/11/1992

MEASURED DISTANCE: 433.00m

D = 116.7 mm

TALLY BOX





MRCU – MAINTENANCE AND REHABILITATION CO-ORDINATION UNIT

Calibration of the Bump Integrator – Landrover No. 60-0-73

TEST SECTION Naukise

L = 433.0 m	Direction: As Merlin Testing		Direction: Reverse	
Test Serial #	BI_V Reading	Time	BI_V Reading	Time
1	70			
2	70			
3	72			
4	71			
5	70			
6	71			
7	72			
8	70			
9	66			
10	68			

DATE : 15 Jan 1995

ROUGHNESS MEASUREMENTS

Landrover No. 60-0-73 Date: 30 Jan 1995

Link: Kadmaha - Sikwari

CHAINAGE FROM KM	CHAINAGE TO KM	BI READING	TIME	REMARKS
0 +000	1 +000	380	01.49	
1 +000	2 +000	421	03.29	
2 +000	3 +000	463	05.26	
3 +000	4 +000	344+89+27	07.25	3+884 - 3+945 Gravel Surface
4 +000	5 +000	206 + 750	10.35	4+527 Diversion start
5 +000	6 +000	314 + 295	12.54	5+302 Diversion end
6 +000	7 +000	374	14.48	
7 +000	8 +000	355	16.40	
8 +000	9 +000	434	18.44	
9 +000	10 +000	433	20.38	
10 +000	11 +000	430	22.48	
11 +000	12 +000	447	24.55	
12 +000	12 ~~+000~~ +103	44	25.30	End
+000	+000			
+000	+000			
+000	+000			
+000	+000			
+000	+000			
+000	+000			
+000	+000			

THE MEASUREMENT OF SURFACE DISTRESS INDEX (SDI)

Introduction

Surface distress is an important visual indicator of pavement deterioration. Surface distress includes all types of defects affecting the integrity of the surface which, if they are left untreated, will seriously reduce the serviceability of the road and the life of the pavement.

Surface distress surveys of the Strategic Network have been undertaken annually by the Planning Branch since fiscal year 1992/93. The information obtained is used to monitor road deterioration and, in particular, to indicate the need for periodic maintenance (resealing) of bitumen surfaced roads. Surface distress information can also be used by the Department to:

- determine if a particular road section exceeds established distress levels for implementing planned maintenance activities or for carrying out rehabilitation;
- provide a consistent and objective assessment of overall pavement condition (good, fair, poor);
- monitor the performance of the pavement and the effectiveness of maintenance activities.

Method of Surface Distress Measurement

There are various methods for collecting surface distress data and these increase in complexity and sophistication according to the quality of information required. The method adopted by the Department is a simplified procedure recommended by the World Bank which has been modified to suit the particular conditions in Nepal and the needs of DOR.

Pavement distress surveys are carried out manually in the Department by trained Highway Engineers working as a two person team; the method in use is a "drive and walk" survey. Surface distress comprises cracking, disintegration (potholes), deformation, texture deficiency, pavement edge defaults and maintenance works (patching). These faults are visually assessed using a 10% sampling procedure and recorded using a cumulative index called a ***surface distress index*** **(SDI)**.

The SDI is a six level rating index from 0 to 5. The rating 0 indicates a pavement surface without any defects, whereas a rating of 5 indicates the maximum possible deterioration. A shoulder condition survey is carried out at the same time using a rating in the range 0 to 4. The three most predominant types of defect present in each sample section are also recorded. The distress elements are divided into two groups: major defects and minor defects. Among the different defect types, cracking, ravelling and potholes are generally characterized by extent and severity, while for rut depth, being continuous in nature, only the severity of the deformation is noted. The defect types and therefore the resulting score is different for bitumen and gravel roads. Tables showing the scoring system, categories of defect and distress type codes for bitumen and gravel roads are given on pages 4 and 5.

The 10% sampling procedure comprises a walk-over survey generally covering the last 100 metre section in each kilometre of the road on which the SDI is to be determined. The full width of the pavement is examined for the 100 metre sample length. To start the survey, the team drives at 10-20 km/hour from the starting point of the section. As in the case of roughness measurements (Annex II), each section will commence and finish at a defined road link node point in the Network referencing system. When the 900 metre point in each kilometre is reached, the team stops and undertakes a walk-over survey of the final 100 metres.

While walking, it is necessary to first identify the major and minor defects and then calculate the percentage of the total defective area for both major and minor defects individually. The shoulder condition is also noted. The results are recorded on a standard form which shows the degree and extent of damage on the road surface rated on a scale of 0 to 5 and the main distress type. A typical record form is given on page 6. The process is then repeated for another 100m sample section in the next km. About 50-60 km of visual distress survey is achievable in one day by a single team.

For Network level applications, the entire Strategic Network should be surveyed each year. DOR has been carrying out pavement distress surveys on the Network since 1993/94 and the data is held in the Planning Branch HMIS.

Data Use

The SDI is averaged over each road link or section under consideration. As noted in the Introduction, the results can be used to provide an objective assessment of pavement condition and to indicate the need for periodic maintenance, rehabilitation or reconstruction. For assessing pavement condition, the terms "good", "fair" and "poor" are used based on the following averaged values of SDI for a particular section of road.

SDI Value	Condition
0 - 1.7	Good
1.8 - 3.0	Fair
3.1 - 5.0	Poor

The above values are based on conditions in Nepal. Planned maintenance can be carried out on roads in good/fair condition and rehabilitation or reconstruction is generally needed for roads in poor condition to bring them to a maintainable state.

Similarly, an indication of the type of pavement remedial action is given by the percentage of the number of sample sections with the given SDI value of a particular link as shown in the following table.

Table of Pavement Remedial Action

Percentage	SDI Values	Action
20%	SDI ¤ 5	Reconstruction
10% - 30%	SDI ¤ 4	Rehabilitation
20% - 30%	SDI ¤ 3	Resealing with local patching
20% - 30%	SDI ¤ 2	Resealing only

The rate of deterioration of the road pavement is important for determining the timing of remedial action. However, in order to produce pavement deterioration curves for Nepal conditions, pavement data, including SDI measurements, must be collected and processed for a period of at least 5 years in order to determine historical trends. Data is not yet available for this length of time for pavements in Nepal but a start has now been made by the Planning Branch in this direction.

PAVEMENT CONDITION SURVEY – SURFACE DISTRESS INDEX

TABLES FOR BLACK TOPPED PAVEMENTS

PAVEMENT DISTRESS SCORE

Score	Incidence of Minor Defects	Incidence of Major Defects
0	None	None
1	1 to 20 m² per 100 metres	1 occurrence
2	< 50% of the area	2 to 4 occurrences
3	>= 50% of the area	< 30% of the area
4	...	>= 30% **or** potholes and base exposed < 20% of the area
5	...	Potholes and exposed base >= 20% of the area

CATEGORIES OF DEFECT AND DISTRESS TYPE CODES

Defect	Code	Minor	Code	Major
Cracking	CN CL M	■ Narrow interconnected cracks (1-3 mm width) ■ Line cracks (Longitudinal or transverse) ■ Sealed crack	CW	■ Wide interconnected cracks (> 3 mm)
Maint. Patches	M	■ Patches		
Texture	RA S S	■ Shallow ravelling or scabbing (< 20 mm) ■ Slickness (texture depth < 1 mm) ■ Bleeding	V	■ Scabbing (> 20 mm depth)
Rutting			RL	■ Rut depth > 15 mm
Pothole			P	■ Pothole (> 30 mm depth, > 150 mm Ø)
Exposed Base			G	■ Exposed base or sub-base, or gravel
Edge Break	ES	■ Short edge break (> 100 mm, < 5 m L.)	EL	■ Long edge break (> 100 mm, > 5 m L.)
Depres./ Humps			D	■ Corrugations

Note: Width applicable to line cracking: 0.5 metre.

PAVEMENT CONDITION SURVEY – SURFACE DISTRESS INDEX

SHOULDER SCORE

Score	High Shoulders	Score	Low Shoulders
0	No drop off		
1	Shoulder slightly raised (< 50 mm)	3	Shoulder drop off small (up to 100 mm)
2	Shoulder raised (>= 50 mm)	4	Shoulder drop off important (more than 100 mm)

TABLES FOR GRAVEL SURFACED ROADS

PAVEMENT DISTRESS SCORE

Score	Incidence of Minor Defects	Incidence of Major Defects
0	None	None
1	1 to 20 m^2 per 100 metres	1 occurrence
2	< 50% of the area	2 to 4 occurrences
3	>= 50% of the area	< 30% of the area
4	...	>= 30% **or** subgrade exposed over less than 20% of the area
5	...	Subgrade exposed over more than 20% of the area

CATEGORIES OF DEFECT AND DISTRESS TYPE CODES

Defect	Code	Minor	Code	Major
Rutting	RS	■ Rut depth < 100 mm	RL	■ Rut depth > 100 mm
Pothole	PS	■ Depression or pothole (< 100 mm depth)	PL	■ Pothole (> 100 mm depth)
Corrug.	O	■ Corrugations		
Expos.			EX	■ Exposed subgrade (> 1 m diameter)
Camber	C	■ Cross fall or crown flat or depressed		
Rocks	R	■ Exposed rocks (> 100 mm size)		

PAVEMENT SURFACE DISTRESS SURVEY

Link No. ________________ From ____________________ To ____________________

Terrain ________________ Surface Type ________________ Date ______________

Location KP	Scores			Width (in metres)		Main Distress Type	Remarks
	Surface	Shoulder Left	Shoulder Right	Pave-ment	Form-ation		

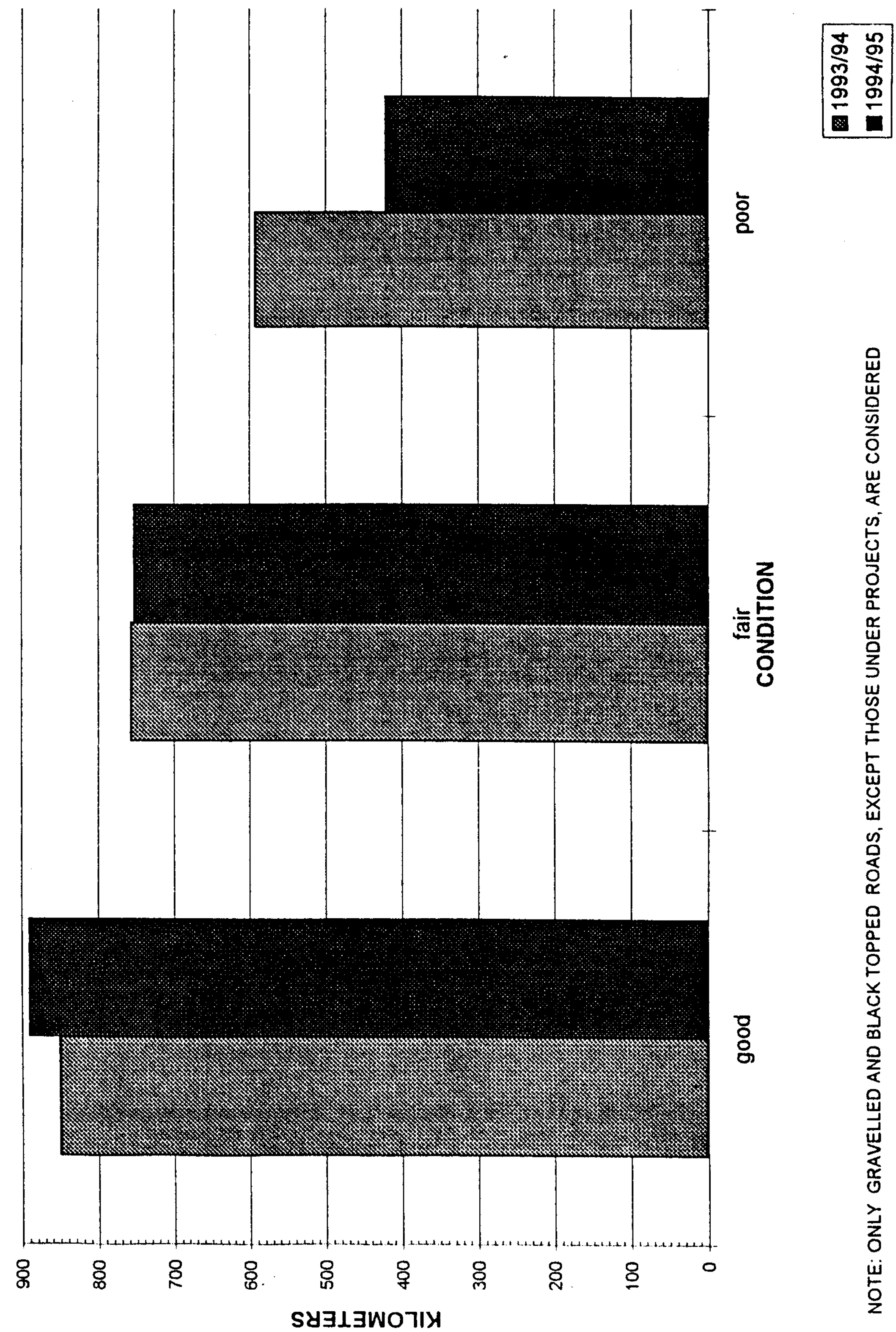
PAVEMENT MANAGEMENT DATA/INFORMATION GUIDELINES

MANAGEMENT LEVEL DATA/INFORMATION ITEMS	QUALITY LEVEL*	COLLECTION AND UPDATE PERIODS	RESPONSIBILITY
1. Network Level			
Road inventory - comprising road length, pavement width, type of surfacing, average curvature and gradient.	IV	Once only, updated annually.	Planning Branch - Divisions to supply initial and revised data which is held on HMIS.
Pavement condition - comprising VMBI and SDI surveys on whole of the Strategic Network.	IV	Annually.	Planning Branch - carried out by local consultants, data held on HMIS.
Average annual daily traffic (AADT) flows recorded by some 26 automatic loggers covering the Strategic Network.	IV	Monthly.	Planning Branch - data collected by Divisions and forwarded through Regions to Planning Branch for storage in HMIS.
Manual vehicle classification counts and axle load surveys to determine seasonal factor, categories, average ESAF.	III/IV	Every 1-3 years across the Strategic Network.	Planning Branch - surveys undertaken by local consultants and data processed by Planning Branch.
Unit costs for reconstruction, rehabilitation and planned maintenance activities averaged separately over the Strategic Network for the Hills and the Terai.	IV	Costs updated annually to cover inflation with a detailed review every 2 years.	Planning Branch - costs prepared and updated from information provided by Foreign Co-operation and Maintenance Branches and the Regions.
VOC/km for the main vehicle classes averaged separately over the Strategic Network for the Hills and the Terai.	IV	Updated annually to suit changes in the price of vehicles, consumables and maintenance.	Planning Branch - the operation and update of the VOC Model is the responsibility of the Traffic Unit.
Establishing existing road investment priorities in the Strategic Network.	N/A	Updated annually.	Planning Branch - priorities based on strategic importance and traffic.
Initial periodic maintenance programme for bitumen roads in the Strategic Network.	N/A	Updated annually.	Planning Branch until training programme under the RMP completed. Responsibility then passed to the Regions.
3 year and 5 year rolling programmes of rehabilitation and reconstruction projects on the Strategic Network.	N/A	Updated annually.	Planning Branch - to be prepared and updated on basis of traffic and pavement condition.
2. Operations Level			
Regional road inventory - comprising road length, pavement width, type of surfacing, shoulder width and type.	III/IV	Once only, updated annually.	Regions - inventory compiled from data supplied by the Divisions. Copy of data to be forwarded to Planning Branch.
Regional traffic information covering average levels and broad classification for all roads.	N/A	Updated annually.	Regions - information provided by Planning Branch Traffic Unit. Logger data provided monthly by Regions to Planning Branch.
Existing regional road investment priorities in the Strategic Network	N/A	Updated annually	Regions - information obtained from the Planning Branch.
Regional pavement condition information covering regional network and individual road sections.	N/A	Updated annually.	Regions - information provided by the Planning Branch Pavement Unit.

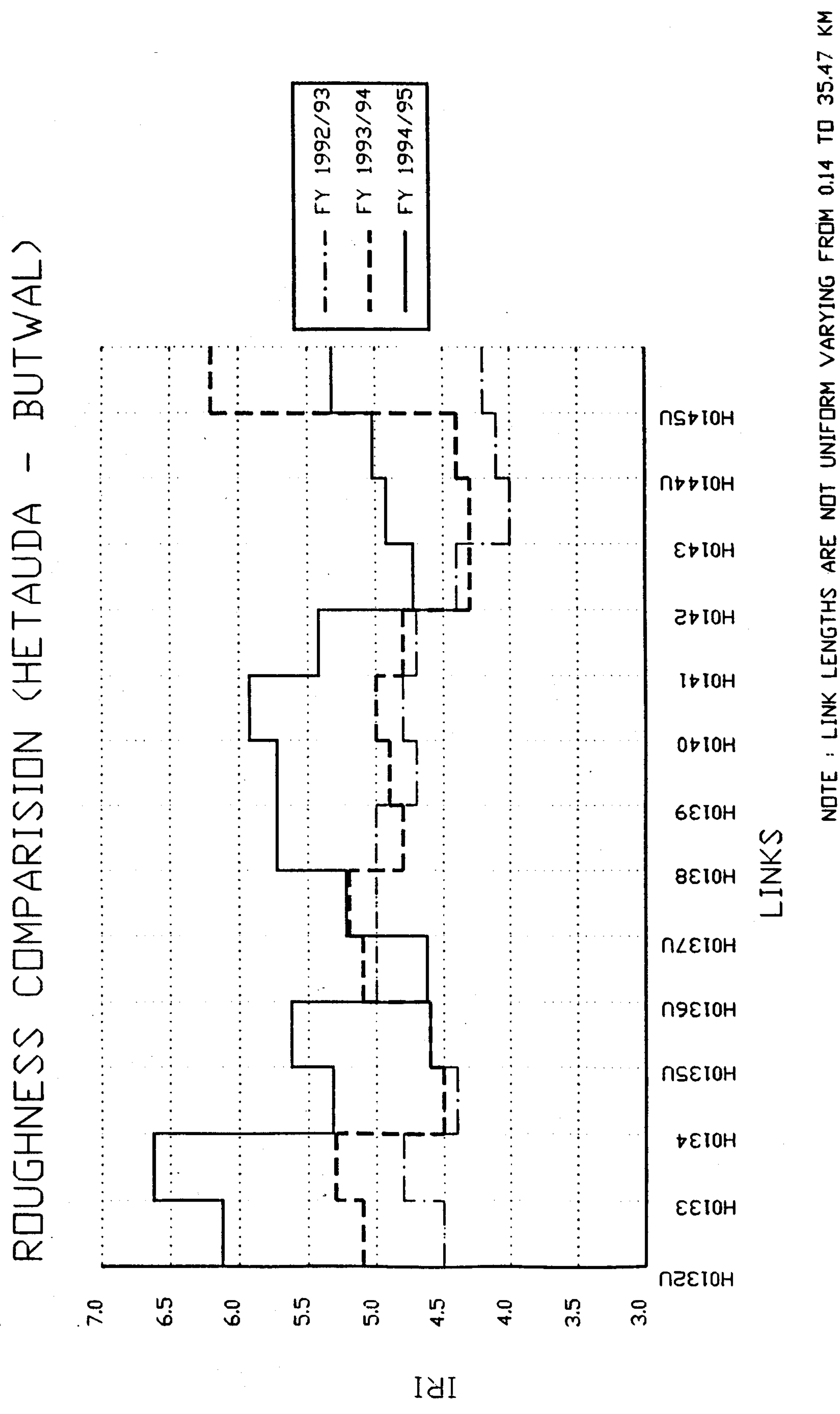
MANAGEMENT LEVEL DATA/INFORMATION ITEMS	QUALITY LEVEL*	COLLECTION AND UPDATE PERIODS	RESPONSIBILITY
Regional pavement condition information covering regional network and individual road sections.	N/A	Updated annually.	Regions - information provided by the Planning Branch Pavement Unit.
Regional 3 year rolling programme of reconstruction and rehabilitation.	N/A	Updated annually.	Regions - information to be obtained from Planning Branch.
Outline annual work programme for each Division	N/A	Updated for major changes.	Regions - work programme and update information supplied by the Divisions.
Feedback on overall road performance and road elements to the Design Branch.	N/A	Annually	Regions
Divisional road inventory for each Strategic Network road in the Division covering all maintainable aspects of the road.	III	Once only, updated as necessary.	Divisions.- copy of original and update data to be forwarded to Region.
Preparation of detailed work schedules for planned and ad-hoc maintenance activities on each road. in the Division.	N/A	Annually	Divisions
Collection of data from automatic traffic loggers.	N/A	Weekly	Divisions - data passed monthly to the Region.
Divisional pavement condition information covering the network and individual road sections.	N/A	Annually.	Divisions - information provided by the Region.
Divisional 3 year rolling programme of reconstruction and rehabilitation.	N/A	Annually.	Divisions - information provided by the Region.
Existing divisional road investment priorities in the Strategic Network	N/A	Annually.	Divisions - information provided by the Region.
Divisional traffic information covering average levels and broad classification for all roads.	N/A	Annually.	Divisions - information provided by the Region.
Feedback on overall road performance and road elements to the Regions.	N/A	Annually	Divisions

*** As defined in the World Bank Technical Paper, "Information Systems for Road Management: Draft Guidelines on System Design and Data Issues".**

PAVEMENT CONDITION IN FY 1993/94 AND 1994/95



NOTE: ONLY GRAVELLED AND BLACK TOPPED ROADS, EXCEPT THOSE UNDER PROJECTS, ARE CONSIDERED


ROUGHNESS COMPARISION (HETAUDA - BUTWAL)
FY 1992/93
FY 1993/94
FY 1994/95
IRI
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
H0132U
H0133
H0134
H0135U
H0136U
H0137U
H0138
H0139
H0140
H0141
H0142
H0143
H0144U
H0145U
LINKS
NOTE : LINK LENGTHS ARE NOT UNIFORM VARYING FROM 0.14 TO 35.47 KM