Chapter 26*

MAINTENANCE

26.1 PROBLEMS

The following are some of the problems relating to hill road maintenance in developing countries.

- o The value of the average annual loss of road network and the loss of vehicle operating costs in relation to the annual budget of the country can be considerable. This is because of the fact that lack of a timely routine and recurrent and periodic maintenance lead to a reduced design life and premature reconstruction needs.

- o Maintenance problems start with construction since these are inversely proportional to the constructed quality which is a function of design standards and quality control during construction.

- o Poor maintenance of hill roads not only effects the roads but also contributes to erosion, gullying, deforestation, and landslides. Traditional hill road maintenance practices are not sensitive to environmental concerns.

- o Low initial cost of hill roads leads to high costs of maintenance or intensive maintenance management systems, both are normally not conducive to the conditions in developing countries.

26.2 GUIDELINES

- o Prepare annual maintenance plans with due regard to the level of routine as well as recurrent and periodic maintenance envisaged in original designs and plans.

- o Provide for emergency maintenance on the basis of hazards and risks.

- o Provide for the evaluation of road conditions, including pavement, landslides, structures, slope stability, and road furniture, in the annual budget programmes so that sufficient lead time is available for development of rehabilitation alternatives and systematic management systems for subsequent years.

- o Select preferred rehabilitation alternatives on the basis of weighting of various criteria for several alternatives and ranking of priority for each alternative. Only tentative designs should be used for comparison. Detailed designing is normally carried out only for the selected alternative.

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* All Figures and Tables that do not credit any source in this chapter are developed by the author for this publication.

- o Conduct frequent short-term and long-term training, for the engineers and overseers of the concerned road agency, on distress identification, condition evaluation, design techniques, quality control, and computer-based data management.

- o Exercise axle load controls in accordance with designed axle loads since the design life is drastically reduced by vehicles with axle loads exceeding the axle load of the design vehicle. It must be noted that the damaging power of a vehicle of axle load Wx in terms of a standard vehicle of axle load W is $(Wx/W)^{4.5}$ approximately.

- o Conduct regular surveys for traffic counts and axle loads to generate the information needed for pavement rehabilitation.

- o Use of emulsified asphalt should be encouraged for low-volume roads since it helps to minimize the use of firewood, reduce air pollution, and speed up surfacing work.

- o Maintain uniform and consistent practices in cost-estimating and record-keeping to generate a proper database and historical records for reliable planning and costing of future maintenance works.

26.3 MAINTENANCE TYPES

Road maintenance of different types has been classified in the following sections.

26.3.1 *Routine Maintenance*

These activities are required irrespective of the engineering characteristics of the road and the density of traffic carried by it. They may, therefore, be considered fixed cost activities and include:

- o grass cutting,
- o drain clearing,
- o recutting ditches,
- o culvert repair (minor repair),
- o bridge repair (minor repair),
- o shallow landslide repair,
- o retaining wall maintenance (minor repair),
- o erosion control, and
- o road sign maintenance.

26.3.2 *Recurrent Maintenance*

These activities may be required at intervals throughout the year. The frequency of the activities varies with traffic. Activities under recurrent maintenance are given below.

a) For Unpaved Road:
  - repairing potholes,
  - dragging,

- grading,
- repairing side drains, and
- planting and revegetation.

b) For Paved Roads:
- repairing potholes up to 1 per cent of the total,
- area of sealed roads per annum,
- surface patching,
- sealing cracks,
- edge repairs,
- gravelling shoulders of sealed roads,
- repairing side drains, and
- planting and revegetating.

26.3.3 *Periodic Maintenance*

These activities are required at intervals of a certain number of years and include:

a) For Unpaved Roads:
- re-gravelling.

b) For Paved Roads:
- surface dressing (resealing) at an interval of 5 to 8 years,
- re-gravelling shoulders,
- road surface marking, and
- improving drains.

Since the frequency of recurrent and periodic activities is dependent upon a number of variable factors, of which engineering characteristics and traffic-loading are the most important, they are considered to be 'variable cost' activities.

26.3.4 *Emergency/Urgent Maintenance*

These activities are normally unforeseeable and unprogrammable. They have to be carried out with minimum delay to avoid danger to traffic. Existence of large-scale hazard maps, or detailed hazard and risk assessments, however, allow the prediction of probable failures. The annual budget plan should make provision for urgent repairs; some of which are as follows:

- o removal of debris,
- o erection of warning signs,
- o construction of diversion,
- o river training,
- o retaining walls, and
- o landslide stabilization/clearance.

26.3.5 *Rehabilitation/Reconstruction*

Works under this include major works involving widening, overlays, removing old surfaces and constructing new pavements, improving drains, culverts, bridges, retaining walls, and stabilization of deep-seated landslides, in order to upgrade the road or significantly extend the service life of an existing road.

26.4 DISTRESSES IN FLEXIBLE PAVEMENTS

Understanding of types and causes of distress is essential for a proper evaluation of pavement conditions. The following discussion provides some background on various types of distress in flexible pavements.

26.4.1 *Name of Distress: Alligator or Fatigue Cracking Description*

Alligator or fatigue cracking is a series of interconnecting cracks caused by fatigue failure of the asphalt concrete surface (or stabilized base) under repeated traffic loading. The cracking commences at the bottom of the asphalt surface (or stabilized base) where tensile stress and strain is highest under a wheel load. The cracks propagate on to the surface initially as one or more longitudinal parallel cracks. After repeated traffic-loading, the cracks connect, forming many-sided, sharp-angled pieces that develop a pattern resembling chicken wire or the skin of an alligator. The pieces are usually less than 1 ft. on the longest side. Alligator cracking occurs only in areas that are subjected to repeated traffic-loading. Therefore, it would not occur over an entire area unless the entire area was subjected to traffic-loading. Alligator cracking does not occur in asphalt overlays over concrete slabs. Pattern-type cracking, which occurs over an entire area that is not subjected to loading, is rated as block cracking and this is not a load-associated distress. Alligator cracking is considered to be a major structural distress.

Severity Levels

1. L** Longitudinal, disconnected hairline cracks running parallel to each other. The cracks are not **spalled**. Initially there may only be a single crack in the wheelpath (defined as Class 1 cracking by the American Association of State Highway Officials (AASHO) Road Test 1950-1960).

2. M** Further development of low severity alligator cracking into a pattern of pieces formed by cracks that may be lightly spalled on the surface. Cracks may be sealed (defined as Class 2 cracking by the AASHO Road Test).

3. H** Medium alligator cracking has progressed so that pieces are more severely spalled at the edges and loosened until the cells rock under traffic. Pumping may exist (defined as Class 3 cracking by the AASHO Road Test).

1.** L : Low severity level 2.** M : Medium severity level 3.** H : High severity level

How to Measure

Alligator cracking is measured in square feet or square metres of surface area. The major difficulty in measuring this type of distress is that many times two or three levels of severity exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be easily divided, the entire area should be rated at the highest severity level present.

26.4.2 *Name of Distress: Bleeding*

Description

Bleeding is a film of bituminous material on the pavement surface which creates a shiny, glass-like, reflecting surface that usually becomes quite sticky. Bleeding is caused by excessive amounts of asphalt cement in the mix and/or low air void contents. It occurs when asphalt fills the voids of the mix during hot weather and then expands on to the surface of the pavement. Since the bleeding process is not reversible during cold weather, asphalt will accumulate on the surface.

Severity Levels

No degrees of severity are defined. Bleeding should be noted when it is extensive enough to cause a reduction in skid resistance.

How to Measure

Bleeding is measured in square feet or square metres of surface area.

26.4.3 *Name of Distress: Block Cracking*

Description

Block cracks divide the asphalt surface into approximately rectangular pieces. The blocks range in size from approximately 1 ft^2 to 100 ft^2. Cracking into larger blocks is generally rated as longitudinal and transverse cracking. Block cracking is caused mainly by shrinkage of the asphalt concrete and daily temperature cycling (which results in daily stress/strain cycling). It is not load-associated, although load can increase the severity of individual cracks from low to medium to high. The occurrence of block cracking usually indicates that the asphalt has hardened significantly. Block cracking normally occurs over a large proportion of pavement area, but sometimes will occur only in non-traffic areas. This type of distress differs from alligator cracking in that alligator cracks form smaller, many-sided pieces with sharp angles. Also, unlike block cracks, alligator cracks are caused by repeated traffic-loading and are, therefore, located only in trafficked areas (i.e., wheelpaths).

Severity Levels

L: Blocks are defined by (1) non-sealed cracks that are non-spalled (sides of the crack are vertical) or where spalling is minor with a 1/4 in (6mm) or less mean width, or by (2) sealed cracks that have a sealant in satisfactory condition to prevent moisture infiltration.

M: Blocks are defined by either (1) sealed or non-sealed cracks that are moderately spalled, (2) non-sealed cracks that are not spalled or have only minor spalling but have a mean width greater than approximately 1/4 in (6 mm), or (3) sealed cracks that are not spalled or have only minor spalling but have a sealant in unsatisfactory condition.

H: Blocks are well-defined by cracks that are severely spalled.

How to Measure

Block cracking is measured in square feet or square metres of surface area. It usually occurs at one severity level in a given pavement section. However, areas of the pavement section having distinctly different levels of severity should be measured and recorded separately.

26.4.4 *Name of Distress: Corrugation*

Description

Corrugation is a form of plastic movement typified by ripples across the asphalt pavement surface. It occurs usually at points where traffic starts and stops. Corrugation usually occurs in asphalt layers that lack stability in warm weather, but may also be attributed to excessive moisture in a sub-grade, contamination of the mix, or lack of aeration of liquid asphalt mixes.

Severity Levels

L: Corrugation causes some vibration of the vehicle which creates no discomfort.

M: Corrugation causes significant vibration of the vehicle which creates some discomfort.

H: Corrugation causes excessive vibration of the vehicle which creates substantial discomfort, and/or a safety hazard, and or vehicle damage, requiring a reduction in speed for safety.

How to Measure

Corrugation is measured in square feet or square metres of surface area. Severity levels are determined by riding in a mid- to full-sized sedan weighing approximately 3,000-3,800 lbs (13.3-16.9 kN) over the pavement inspection unit at the posted speed limit.

26.4.5 *Name of Distress: Depression*

Description

Depressions are localized pavement surface areas having elevations slightly lower than those of the surrounding pavement. In many instances, light depressions are not noticeable until after rain when ponding water creates birdbath areas; but the depressions can also be located without rain because of strains created by oil droppings from vehicles. Depressions can be caused by settlement of the foundation soil or can be built in during construction. Depressions cause roughness and when filled with water of sufficient depth could cause hydroplaning of vehicles.

Severity Levels

L: Depressions cause some bounce of the vehicle which creates no discomfort.

M: Depressions cause significant bounce of the vehicle which creates some discomfort.

H: Depressions cause excessive bounce of the vehicle which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage, requiring a reduction in speed for safety.

How to Measure

Depressions are measured in square feet or square metres in each inspection unit. Each depression is rated according to its level of severity. The severity level is determined by riding in a mid-to full-sized sedan weighing approximately 3,000-3,800 lbs (13.3-16.9 kN) over the pavement inspection unit at the posted speed limit.

26.4.6 *Name of Distress: Joint Reflection Cracking from PCC Slab*

Description

This distress occurs only on pavements having an asphalt concrete surface over a jointed Portland Cement Concrete (PCC) slab, and it occurs at transverse and longitudinal joints (i.e., widening joints). This distress does not include reflection cracking away from a joint or from any other type of base (i.e., cement stabilized, lime stabilized) as these cracks are identified as "Longitudinal and Transverse Cracking." Joint reflection cracking is caused mainly by movement of the PCC slab beneath the asphalt concrete (AC) surface because of thermal and moisture changes; it is generally not load initiated. However, traffic-loading may cause a breakdown of the AC near the initial crack, resulting in spalling. A knowledge of slab dimensions beneath the AC surface will help to identify these cracks.

Severity Levels

L: Cracks have either minor spalling or no spalling and can be sealed or non-sealed. If non-sealed, the cracks have a mean width of 1/4 in (6 mm) or less; sealed cracks are of any width, but their sealant material is in a satisfactory condition to substantially prevent water infiltration. No significant bump occurs when a vehicle crosses the crack.

M: One of the following conditions exists: (1) cracks are moderately spalled and can be either sealed or non-sealed of any width; (2) sealed cracks are not spalled or have only minor spalling, but the sealant is in a condition so that water can freely infiltrate; (3) non-sealed cracks are not spalled or are only lightly spalled, but the mean crack width is greater than 1/4 in (6 mm); (4) low severity random cracking exists near the crack or at the corners of intersecting cracks; or (5) the crack causes a significant bump to a vehicle.

H: (1) Cracks are severely spalled and/or there exists medium or high random cracking near the crack or at the corners of intersecting cracks, or (2) the crack causes a severe bump to a vehicle.

How to Measure

Joint reflection cracking is measured in lineal feet or metres. The length and severity level of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each general portion should be recorded separately. The vehicle used to determine bump severity is a mid- to full-sized sedan weighing approximately 3,000-3,800 lbs (13.3-16.9 kN) over the pavement inspection unit at the posted speed limit.

26.4.7 *Name of Distress: Lane/Shoulder Drop-off or Heave*

Description

Lane/shoulder drop-off or heave occurs wherever there is a difference in elevation between the traffic lane and shoulder. Typically the outside shoulder settles because of consolidation, a settlement of the underlying granular or sub-grade material, or pumping of the underlying material. Heave of the shoulder may occur because of frost action or swelling soils. Drop-off of granular or soil shoulder is generally caused by the blowing away of shoulder material from passing trucks.

Severity Level

Severity level is determined by computing the mean difference in elevation between the traffic lane and shoulder:

L	1/4 - 1/2 in	(6 - 13 mm)
M	1/2 - 1 in	(3 - 25 mm)
H	> 1 in	(> 25 mm)

How to Measure

Lane/shoulder drop-off or heave is measured every 100 ft. (30 m) in inches (or mm) along the joint. The mean difference in elevation is computed from the data and used to determine severity level.

26.4.8 *Name of Distress: Lane/Shoulder Joint Separation*

Description

Lane/shoulder joint separation is the widening of the joint between the traffic lane and the shoulder and is generally caused by movement in the shoulder. If the joint is tightly closed or well sealed, so that water cannot enter (or if there is no joint because of full width paving), then lane/shoulder joint separation is not considered a distress. If the shoulder is not paved (i.e., gravel or grass) then the severity should be rated as high. If a curbing exists, then it should be rated according to the width of the joint between the asphalt surface and curb.

Severity Levels

Severity level is determined by the mean joint opening. No severity level is counted if the joint is well sealed to prevent moisture intrusion:

L	0. 04 - .12	in	(1 - 3 mm)
M	> .12 - .40	in	(>3 - 10 mm)
H	>.40	in	(>10 mm) (also a non-paved shoulder)

How to Measure

Lane/shoulder joint separation is measured in inches (or millimetres) at about 50 ft (15.2 m) intervals along the sample unit. The mean separation is used to determine severity level.

26.4.9 *Name of Distress: Longitudinal and Transverse Cracking (Non-PCC Slab Joint Reflective)*

Description

Longitudinal cracks are parallel to the pavement's centreline or laydown direction. They may be caused by (1) a poorly constructed, paving lane joint, (2) shrinkage of the AC surface because of low temperatures or hardening of the asphalt, or (3) a reflective crack caused by cracks beneath the surface course, including cracks in PCC slabs (but not at PCC slab joints). Transverse cracks extend across the pavement centreline or direction of laydown. They may be caused by items 2 or 3 above. These types of cracks are not usually load associated.

Severity Levels

L: Cracks have either minor spalling or no spalling, and cracks can be sealed or non-sealed. If sealed, cracks have a mean width of 1/4 in. (6 mm) or less; sealed cracks are of any width, but their sealant material is in satisfactory condition and substantially prevents water infiltration. No significant bump occurs when a vehicle crosses the crack.

M: One of the following conditions exists:

(1) cracks are moderately spalled and can either be sealed or non-sealed of any width;
(2) sealed cracks are not spalled or have only minor spalling, but the sealant is in such a condition that water can freely infiltrate;
(3) non-sealed cracks are not spalled or have only minor spalling but mean crack width is greater than 1/4 in (6 mm);
(4) low severity random cracking exists near the crack or at the corners of intersecting cracks; or
(5) the crack causes a significant bump to a vehicle.

H: (1) Cracks are severely spalled and/or medium or high random cracking exists near the crack or at the corners of intersecting cracks, or
(2) the crack causes a severe bump to a vehicle.

How to Measure

Longitudinal and transverse cracks are measured in lineal feet or lineal metres. The length and severity of each crack should be identified and recorded. If the crack does not have the same severity level along its entire length, each general portion of the crack having a different severity level should be recorded separately. The vehicle used to determine bump severity is a mid-to full-sized sedan weighing approximately 3,000-3,800 lbs (13.3-16.9 kN) over the pavement inspection unit at the posted speed limit.

26.4.10 *Name of Distress: Patch Deterioration*

Description

A patch is an area where the original pavement has been removed and replaced with either similar or different material.

Severity Levels

L: Patch is in a very good condition and is performing satisfactorily.
M: Patch has somewhat deteriorated, having low to medium levels of any types of distress.
H: Patch has badly deteriorated and will soon need replacement.

How to Measure

Each patch is measured in square feet or square metres of surface area. Even if a patch is in excellent condition it is still rated as having low severity.

26.4.11 *Name of Distress: Polished Aggregate*

Description

Aggregate polishing is caused by repeated traffic applications. Polished aggregate is present when close examination of a pavement reveals that the portion of aggregate extending above the asphalt is either very small or has no rough or angular aggregate particles to provide good skid resistance.

Severity Levels

No degrees of severity are defined. However, the degree of polishing should be significant in reducing skid resistance before it is included as a distress.

How to Measure

Polished aggregate is measured in square feet or square metres of surface area. The existence of polishing can be detected by both visually observing and running the fingers over the surface.

26.4.12 *Name of Distress: Potholes*

Description

A bowl-shaped hole of various sizes in the pavement surface. The surface has broken into small pieces by alligator cracking or by localized disintegration of the mixture, and the material is removed by traffic. Traffic loads force the underlying materials out of the hole, increasing the depth.

Severity Levels

Area	(ft^2)	< 1	1-3	> 3
Depth-ins.(mm)	(m^2)	< 0.1	0.1-0.3	> 0.3
< 1	(< 25)	L	L	M
1-2	(25-50)	M	M	H
> 2	(> 51)	M	H	H

How to Measure

Potholes are counted in numbers of holes of each severity level in the inspection unit.

26.4.13 ***Name of Distress: Pumping and Water Bleeding***

Description

Pumping is the ejection of water and fine materials under pressure through cracks under moving loads. As the water is ejected it carries fine material resulting in progressive material deterioration and loss of support. Several cases of pumping of stabilized base materials have been observed; for example, surface staining or accumulation of material on the surface close to cracks is evidence of pumping. Water bleeding occurs where water seeps slowly out of cracks in the pavement surface.

Severity Levels

L: Water bleeding exists or water pumping can be observed when heavy loads pass over the pavement. However, no fines (or only a very small amount) can be seen on the surface of the pavement.

M: Some pumped material can be observed near cracks in the pavement surface.

H: A significant amount of pumped material exists on the pavement surface near the cracks.

How to Count

If pumping or water bleeding exists anywhere in the sample unit it is counted as occurring.

26.4.14 ***Name of Distress: Ravelling and Weathering***

Description

Ravelling and weathering are the wearing away of the pavement surface caused by the dislodging of aggregate particles (ravelling) and loss of asphalt binder (weathering). They generally indicate that the asphalt binder has hardened significantly.

Severity Levels

L: Aggregate or binder has started to wear away but has not progressed significantly.

M: Aggregate and/or binder have worn away and the surface texture is moderately rough and pitted. Loose particles generally exist.

H: Aggregate and/or binder have worn away and the surface texture is severely rough and pitted.

How to Measure

Ravelling and weathering are measured in square feet or square metres of surface area.

26.4.15 ***Name of Distress: Rutting***

Description

A rut is a surface depression in the wheelpaths. Pavement uplift may occur along the sides of the rut. However, in many instances, ruts are noticeable only after a rainfall when the wheelpaths are filled with water. Rutting stems from a permanent deformation in any of the pavement layers or sub-grade, usually caused by consolidation or lateral movement of the materials caused by traffic loads. Rutting may be caused by plastic movement in the mix in hot weather or inadequate compaction during construction. Significant rutting can lead to major structural failure of the pavement and hydroplaning potential. Wear of the surface in the wheelpaths from studded tires can also cause a type of rutting.

Severity Levels

Severity	Mean Rut Depth Criteria
L	1/4 - 1/2 in. (6 - 13 mm)
M	> 1/2 - 1 in. (13 - 25 mm)
H	> 1 in. (> 25 mm)

How to Measure

Rutting is measured in square feet or square metres of surface area, and its severity is determined by the mean depth of the rut. To determine the mean rut depth, a 4 ft (1.2 m) straight edge should be laid across the rut and the maximum depth measured. The mean depth should be computed from measurements taken every 20 ft (6 m) along the length of the rut.

26.4.16 ***Name of Distress: Slippage Cracking***

Description

Slippage cracks are crescent or half-moon shaped cracks generally having two ends pointed into the direction of the traffic. They are produced when braking or turning wheels cause the pavement surface to slide and deform. This usually occurs when there is a low strength surface mix or poor bond between the surface and the next layer of pavement structure.

Severity Levels

No degrees of severity are defined. It is sufficient to indicate that a slippage crack exists.

How to Measure

Slippage cracking is measured in square metres or in square feet of surface area within the inspection unit.

26.4.17 *Name of Distress: Swell*

Description

Swell is characterized by an upward bulge in the pavement's surface. A swell may occur sharply over a small area or as a longer, gradual wave. Either type of swell can be accompanied by surface cracking. A swell is usually caused by frost action in the sub-grade or by swelling soil, but a swell can also occur on the surface of an asphalt overlay (over PCC) as a result of a blow-up in the PCC slab. They can often be identified by oil droppings on the surface.

Severity Levels

L: Swell causes some bounce of the vehicle which creates no discomfort.
M: Swell causes significant bounce of the vehicle which creates some discomfort.
H: Swell causes excessive bounce of the vehicle which creates substantial discomfort, and/or a safety hazard, and/or vehicle damage, requiring reduction in speed for safety.

How to Measure

Swells within the inspection unit are measured in square feet or square metres. Severity level is determined by riding in a mid-to full-sized sedan weighing approximately 3,000-3,800lbs (13.3-16.9 kN) over the pavement inspection unit at the posted speed limit.

26.5 PAVEMENT EVALUATION AND RATING FOR PAVEMENT MANAGEMENT AND TENTATIVE DECISIONS ON PAVEMENT REHABILITATION

Pavement evaluation has two distinct purposes : (1) evaluation of distress types and pavement conditions for rehabilitation decisions and (2) evaluation of pavement performance versus time for pavement management decisions.

Pavement rehabilitation is performed for a combination of two basic reasons: (1) to correct existing distress and improved ride quality and (2) to increase the structural capacity of the pavement. These reasons dictate the type of data that must be collected during pavement evaluation.

Pavement management is the process of allocating limited resources in order to maximize the quality of the pavement available to the user. This often involves comparison of pavement quality versus time in order to schedule rehabilitation before deterioration becomes excessive. Pavement evaluations that indicate general conditions are most useful for Pavement Management.

26.5.1 *Pavement Roughness*

The preceding discussion implies that a measure of pavement roughness could be useful in both Pavement Rehabilitation and Pavement Management. A 'rough' section would justify further investigation to determine appropriate rehabilitation methods. Relative roughness comparisons could be a part of the decision concerning which sections to rehabilitate in any given year.

Consider a group of people riding in an automobile at the legal limit. As a group they could probably come to a decision as to how good the ride quality was. As the quality of ride changed, they probably could decide among themselves which section of the pavement was most in need of rehabilitation.

In order to better quantify their ratings, the riders could establish a numerical scale for each section they rated. A range of five for perfectly smooth to zero for "I'd rather walk" could be used. The whole scale could be:

5	Very Good
4	Good
3	Fair
2	Poor
1	Very Poor
0	

This scale is used for the Present Servicability Rating, or PSR. A rating of 2.5 is generally considered the minimum acceptable value for primary highway pavements and a rating of 2.0 is considered the minimum acceptable value for secondary roads.

Though obviously simple and fairly rapid, the PSR rating system is quite sensitive to the variability of the raters. Decreased variability can be achieved by increasing the number of raters, but the increase can be substantial (say from 3 to 11 raters) to achieve a decrease in variability (reduce standard error from 1.0 to 0.5). Other variables can include type of automobile, traffic conditions, and time of day.

The most visible cause of roughness and loss of ride quality is surface distress. Not only does the identification of surface distress lead to a better understanding of the cause of pavement deterioration, it also helps with the analysis of pavement deficiency and the prediction of future performance. A thorough understanding of pavement distress, its frequency, and causes is essential for efficient pavement rehabilitation.

Information on pavement distress is collected by means of a Distress Survey. A Pavement Serviceability Rating should be carried out for each kilometre every year. Roughness is also measured in terms of Present Serviceability Index (PSI) by continuous measurement of the number of bumps per kilometre with the help of a road meter.

26.5.2 *Pavement Condition Rating*

Once a detailed distress survey has been conducted, this information can be used to determine a pavement condition rating for each pavement section. Many pavement condition rating systems use the idea of 'deduct value' in which points are taken away from a perfect score (say 100) for each distress found. The amount deducted varies with distress type and severity. Thus, a pavement condition rating not only conveys information relating to ride quality, as do PSR and PSI, it also relates to structural deterioration through consideration of actual distresses.

Moisture either causes or contributes to many of the pavement distresses. Moisture effects can range from stripping in asphalt concrete and freeze-thaw damage in Portland Cement Concrete to loss of support caused by a saturated base in the sub-grade layers. A thorough distress survey should include consideration of drainage and moisture effects. See Tables 26.1 and 26.2 for an example of formats for pavement condition evaluations and Tables 26.3 and 26.4 for rating values. Each user agency should modify the distress types, rating values, and weightages for maintenance strategies to suit its own conditions.

26.6 PAVEMENT EVALUATION FOR REHABILITATION DECISIONS

Determination of preferred alternative for rehabilitation of a road pavement requires identification, comparison, and ranking of various candidate solutions. The given road pavement, therefore, needs to be evaluated for several factors such as those in Table 26.1.

Once the preferred alternative is decided, the detailed of design of the pavement rehabilitation work involves field and laboratory tests to ascertain :

- o surface deflection,
- o thickness of pavement layers and properties of pavement materials,
- o road resistance,
- o roughness,
- o climatic variations, and
- o further details on traffic, highway geometrics, and drainages.

Figure 26.1 and illustrates the pavement rehabilitation selection process and an example of the method for selecting rehabilitation alternatives respectively. Surface deflection measurements and soil resistance are discussed briefly in the following section.

26.6.1 *Surface Deflection*

Surface deflection is directly related to the structural capacity of a pavement : the higher the deflection, the more the accumulated fatigue damage of the pavements that eventually leads to loss of the structural integrity of the pavement.

Surface deflection measurements are a part of testing called non-destructive testing (NDT). A variety of NDT devices are available today; all attempts to lead the pavement in some way and measure response, usually by measuring the deflection at various distances from the point of load.

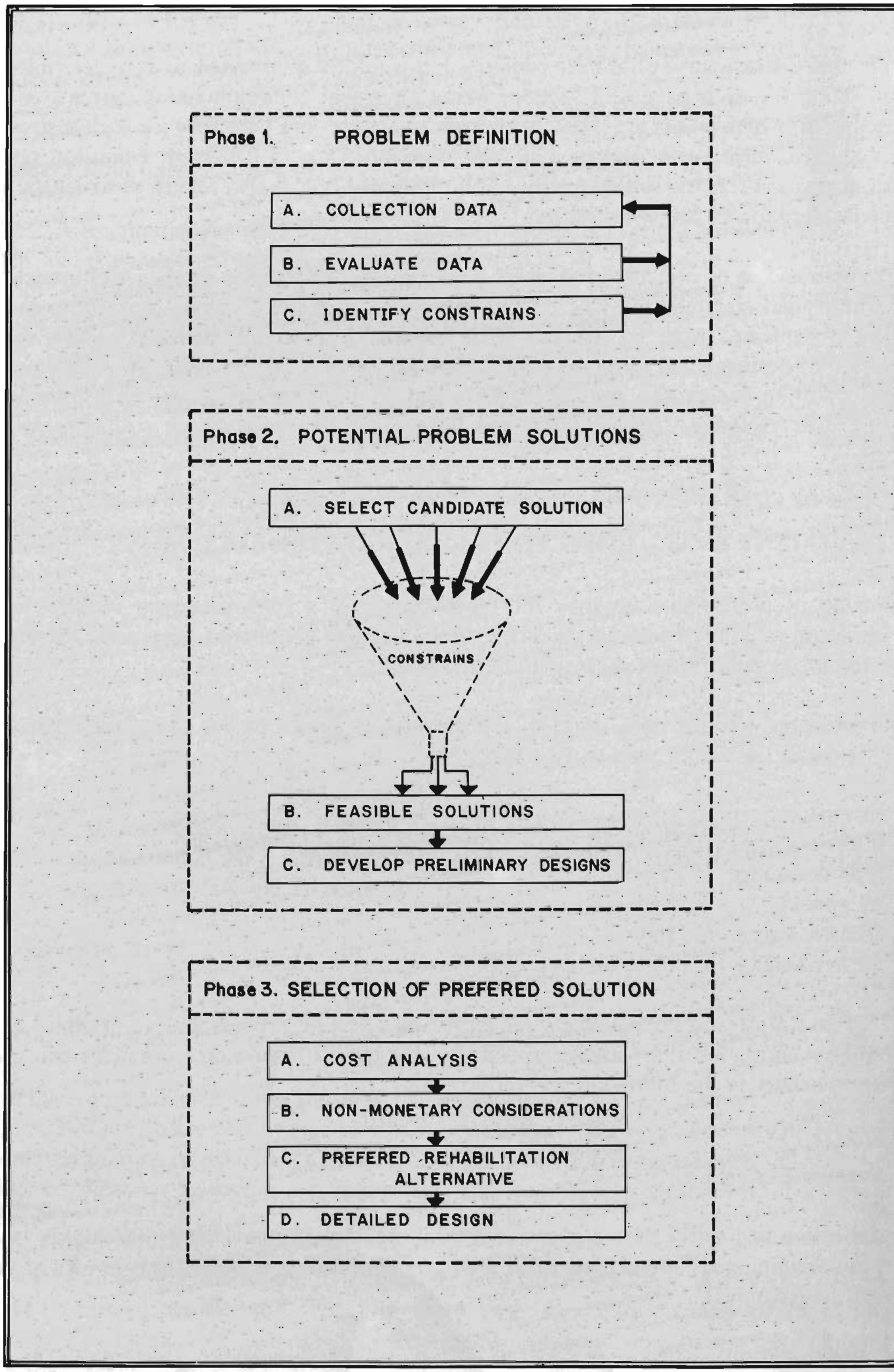

Fig. 26.1 The pavement rehabilitation selection process

Table 26.1 Pavement condition evaluations

ROAD...DISTRICT...DATE.........................

KM/ CHAINAGE	PRESENT SERVICABILITY RATING PSR	BITUMINOUS PAVEMENTS																							PAVEMENT CONDITION RATING PCR
		RUTTING PAVEMENT WEAR			CORRUGATION WAVES, SAGS, HUMPS % ROAD WAYS 1) 1-25% 2) 25-75% 3) Over 75%			ALLIGATOR CRACKING 1) Hairline 2) Spalling 3) Spalling and Pumping				RAVELLING OR FLUSHING 1) Slight 2) Moderate 3) Severe				LONGITUDINAL CRACKING			TRANSVERSE CRACKING NO/STATION OF 30 M 1) 1-99 2) 100-199 3) 200 Plus			PATCHING % AREA/STATION OF 30 M			
		1/4" to 1/2"	1/2" to 3/4"	OVER 3/4"	1/8 CHANGE/3M	1/2" - 12 m m CHAINAGE/3 m	OVER 4" CHAINAGE 3 M	1-24% WHEEL TRACK/30 M	25-49% WHEEL TRACK/30 M	50 to 74% WHEEL TRACK/30 M	75-150% WHEEL TRACK/30 M	LOCALIZED	WHEEL PAMS	ENTIRE LANE	R-RAVELLING F-FLUSHING	LESS THAN 1/4"	OVER 1/4"	SPALLED	1/8" to 1/4"	OVER 1/4"	SPALLED	0.0" - 0.50"	0.50" - 1.0"	OVER 100"	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	

Table 26.1 Pavement condition evaluations (Contd.)

ROADS.. DISTRICT.. DISTRICT...

KM/ CHAINAGE	LAYER TYPE/THICKNESS				W.T. and H.F.L.		TRAFFIC				SHOULDERS			DRAINAGE CONDITION							
	SURFACE	BASE	SUB-BASE	SUB-GRADE TYPE & CBR	DEPTH OF WATER TABLE BELOW ROAD SURFACE	DEPTH OF H.F.L. ABOVE BELOW ROAD SURFACE	AGE OF PAVEMENT YEARS	NO OF OVERLAYS & TOTAL O.L. THICKNESS IN CM.	TRAFFIC AADT	AV EQUIVALENCY ESA	WIDTH	TYPE	ABOVE (+) OR BELOW (-) FROM ROAD	(%) CAMBER FROM CENTRE	(%) OUT OR SLOPE	VALLEY CURVES AND OTHER POOLS	SIDE DRAINAGE CHOKED	CULVERTS CHOKED	OTHER COMMENTS, REMARKS		
	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44		

Table 26.2 Pavement condition ratings and budget proposals for FY

SHEET .....1 of 1 ....

RATER ....

ROAD .... DISTRICT .... DATE ....

ROAD	KM/ CHAINAGE	RATING FOR BUDGE PRIORITY RANKING		RATING FOR REHABILITATION METHODS				PROPOSED BUDGET AMOUNT						REMARKS
		PCR-PMS	Mean PCR-PMS	PCR-PROGRAM	TYPE OF MAINTENANCE RECOMMENDED			Routine @ Rs/Km	Reseal @ Rs/Km	Overlay @ Rs/Km	Re-Construction	Emergency @ Rs/Km	Total	TENTATIVE GUIDELINES PCR-PROG — TYPE OF MAINTENANCE 0 to 30 — Reconstruction 31 to 65 — Overlay 66 to 80 — Reseal (DBST. Slurry Seal) 91 to 100 — Routine Maintenance
					Routine (RT)	Overlay (O)	Re-Construct (RC)							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Table 26.3 Flexible pavement deduct values (for priority ranking for annual budget proposal)

		Negative values are assigned to the failures by degree					
		PMS					
RUTTING PAVEMENT WEAR	Average Depth in Inches 1) 1/4-1/2" 2) 1/2-3/4" 3) Over 3/4"	Throughout Rated Section					
		None	1/4-1/2	1/2-3/4	3/4+		
			0	0°	0		Negative Values
CORRUGATION WAVES, SAGS, HUMPS,	% of Roadway 1) 1-25 2) 26-75 3) 76+	Change Per 10 Feet in Inches					
		None	1/4-2	2-4	4+		
			0	0	0		
			0	0	0		Negative
			0	0	0		Values
ALLIGATOR CRACKING	1) Hairline 2) Spalling 3) Spalling and Pumping	Per cent of Wheel Track per Station					
		None	1-24	25-49	50-74	75+	
			20	25	30	35	
			35	40	45	50	Negative
			50	55	60	65	Values
RAVELLING OR FLUSHING	1) Slight 2) Moderate 3) Severe		Localized	Wheel-Paths	Entire Lane		
			0	0	0		
			0	0	0		Negative
			0	0	0		Values
LONGITUDINAL CRACKING	Lineal Feet Per Station 1) 1-99 2) 100-199 3) 200+	Average Width in Inches					
		None	1/8-1/4	1/4+	Spalled		
			5	15	30		
			15	30	45		Negative
			30	45	60		Values
TRANSVERSE CRACKING	Number Per Station 1) 1-4 2) 5-9 3) 10+	Average Width in Inches					
		None	1/8-1/4	1/4+	Spalled		
			5	10	15		
			10	15	20		Negative
			15	20	25		Values
PATCHING	% Area Per Station 1) 1-5 2) 6-75 3) 26+	Average Depth in Inches					
		None	0-1/2	1-2/1	1+		
			10	15	20		
			15	20	25		Negative
			20	25	30		Values

Table 26.4 Flexible pavement deduct values

(for selecting type of maintenance and preparations of tentative annual program)

		Negative values are assigned to the failures by degree					
		Programming					
RUTTING PAVEMENT WEAR	Average Depth in Inches	Throughout Rated Section					
		None	1/4-1/2	1/2-3/4	3/4+		
	1) 1/4-1/2"						
	2) 1/2-3/4"		5	12	20		Negative Values
	3) Over 3/4"						
CORRUGATION WAVES, SAGS, HUMPS,	% of Roadway	Change Per 10 Feet in Inches					
		None	1/4-2	2-4	4+		
	1) 1-25		0	2	3		
	2) 26-75		0	3	4		Negative
	3) 76+		0	4	5		Values
ALLIGATOR CRACKING		Per cent of Wheel Track per Station					
		None	1-24	25-49	50-74	75+	
	1) Hairline		2	5	10	15	
	2) Spalling		5	10	15	20	Negative
	3) Spalling and Pumping		10	15	20	25	Values
RAVELLING OR FLUSHING			Localized	Wheel-Paths	Entire Lane		
	1) Slight		0	0	0		
	2) Moderate		5	10	15		Negative
	3) Severe		10	15	20		Values
LONGITUDINAL CRACKING	Lineal Feet Per Station	Average Width in Inches					
		None	1/8-1/4	1/4+	Spalled		
	1) 1-99		10	15	20		
	2) 100-199		15	20	25		Negative
	3) 200+		20	25	30		Values
TRANSVERSE CRACKING	Number Per Station	Average Width in Inches					
		None	1/8-1/4	1/4+	Spalled		
	1) 1-4		8	10	15		
	2) 5-9		9	12	17		Negative
	3) 10+		10	15	20		Values
PATCHING	% Area Per Station	Average Depth in Inches					
		None	0-1/2	1-2/1	1+		
	1) 1-5		2	5	7		
	2) 6-25		5	7	10		Negative
	3) 26+		7	10	15		Values

NDT deflection devices can be categorized according to how they produce the deflection when slowly applied to static loading, vibratory, or steady-state loading, or to impact loading. An ideal testing device would produce a load of the same intensity and duration as a fully-loaded truck travelling at normal speed. The various NDT devices consist of this ideal loading.

26.6.2 *Precautions for Interpretation of Pavement Deflection Data*

Layer thickness must be known. Either construction records or field cores can be used to provide information on layer thickness and properties.

Moisture affects response. Moisture adversely affects the load-carrying capacity of sub-grade and unbound bases. Comparisons of deflection should consider moisture effects.

Temperature affects response. Asphalt is quite temperature-sensitive. The black also absorbs solar radiation easily and creates a temperature gradient in the asphalt that can give a different stiffness at the top and bottom of the asphalt concrete layer. Pavement temperature, or at least air temperature, should be recorded whenever deflection is measured in flexible pavements. Temperature effects can be minimized if deflection measurements are made on overcast days; and mid-morning or mid-evening when temperature gradients are minimized.

The Benkleman Beam is a simple device for non-destructive testing of deflection under static load. The deflections are usually measured at 20 to 50m intervals on outer wheelpaths. Method of deflection testing may vary for the standard design method to be adopted for pavement design. Appropriate testing and design studies should be referred to before deflection testing.

26.6.3 *Skid Resistance*

Skid resistance is the force developed when a tire is prevented from rotating slides along the pavement surface. The following definitions are helpful for the understanding of skid resistance.

Hydroplaning : Separation of wheel from pavement surface by water. Tends to occur when there is an abnormally thick water layer on the pavement or the vehicle speed is high.

Pavement Texture : Generates resistance to sliding and facilitates expulsion of water from the tire - pavement interface.

Pavement Micro-texture : Controls contact between tire rubber and pavement surface. Relates to the surface texture of individual particles.

Pavement Macro-texture : Controls the escape of water from under the tire hence loss of skid resistance with increased speed.

The purpose of skid resistance measurement is to prevent or reduce skid-related accidents. It is generally recognized that there is an obligation to provide transportation users with a roadway that is reasonably safe. Skid-resistance measurements permit the identification of areas in need of rehabilitation to improve resistance.

When considering friction between two materials, we define a coefficient of friction:

$$u = F/L$$

where,

u = coefficient of friction,
F = resistance to motion in plane of interface between two materials, and
L = load perpendicular to interface.

This is good on a small scale when both materials are homogeneous. However, for pavements that are heterogeneous on the level of tire-pavement contact, it is more useful to talk of a friction factor, f:

$$f = F/L.$$

Still, this friction factor applies only to specific conditions of the road surface, tire material and texture, and surface moisture. In order to quantify skid-resistance for a particular pavement, we define a skid number (SN) as :

$$SN = F = F/L$$

for a standardized tire at constant speed (usually 40 mph), along an artificially-wetted pavement (ASTM E 274). This is to stimulate emergency braking.

It is important to note that the above definition of SN is for a wet pavement. Skid resistance is seldom a problem on dry pavement. Moisture severely reduces the friction between tire and road surface. This is further complicated by rutting because it causes an accumulation of water in the wheelpath which could lead to hydroplaning.

A minimum skid-resistance as specified by a skid number (SN) of 37 is suggested by the National Cooperative Highway Research Programme (NCHRP) Report 37.

It should be remembered that in addition to road-tire interface, skid-resistance also depends on :

- vehicle design,
- driver behavior,
- highway geometrics, and
- traffic characteristics.

26.6.4 *Priority Ranking of Rehabilitation Alternatives*

Tables 26.5 and 26.6 and Figure 26.1 illustrate an overall pavement evaluation checklist, rehabilitation selection process, and method for selecting rehabilitation alternatives in order.

Table 26.5 Overall pavement evaluation summary and checklist

Sub-grade Evaluation

Structural support:	Low, Medium, High.
Moisture softening potential:	Low, Medium, High.
Temperature problems:	None, Frost Heaving, Freeze-Thaw Softening.
Swelling Potential:	Yes, No.

Previous Maintenance Performed Evaluation

Minor, Normal, Major.	
Has lack of maintenance contributed to deterioration ?	Yes, No.
Describe: ______________________________.	

Rate of Deterioration Evaluation

Long-Term:	Low, Normal, High.
Short-Term:	Low, Normal, High.

Traffic Control during Construction

Are detours available so that the facility can be closed ?	Yes, No.
Must construction be accomplished under traffic ?	Yes, No.
Could construction be done in off-peak hours ?	Yes, No.
Describe: ____________________.	

Geometric and Safety Factors

Current Capacity:	Adequate, Inadequate.
Future Capacity:	Adequate, Inadequate.
Widening required now:	Yes, No.
List high - accident locations:	____________________.
Bridge clearance problems:	____________________.
Lateral obstruction problems:	____________________.
Utility problems:	____________________.
Bridge-pushing problems:	____________________.

Traffic Loading

ADT (two-way):	____________________.
AADT (two-way):	____________________.
Accumulated 18-kip Equivalent	
Single Axle Load (ESAL):	____________________.
Current 18-kip ESAL/year:	____________________.

Shoulders

Pavement Condition:	Good, Fair, Poor.
Localized Deteriorated Areas:	Yes, No.

Table 26.5 (Cont.)

Structural Evaluation	
Existing distress:	Little or no load-associated distress. Moderate load-associated distress. Major load-associated distress.
Structural Load-Carrying Capacity Deficiency:	Yes, No.
Functional Evaluation	
Roughness:	Very Good, Good, Fair, Poor, Very Poor.
Measurement:	________.
Present Serviceability Index/Rating:	________.
Skid Resistance:	Satisfactory, Questionable, Unsatisfactory.
Rutting Severity:	Low, Medium, High.
Variation of Condition Evaluation	
Systematic variation along project	Yes, No.
Systematic variation between lanes:	Yes, No.
Localized variation (very bad areas) along project:	Yes, No.
Climatic Effects' Evaluation	
Climatic Zone	
Moisture Region	I Moisture throughout year. II Seasonal moisture. III Very little moisture.
Temperature Region:	A Severe frost penetration. B Freeze-thaw cycles. C No frost problems.
Severity of moisture-accelerated damage:	Low, Medium, High.
Describe (asphalt stripping, pumping)	________.
Sub-surface drainage capability-BASE:	Satisfactory, Marginal, Unacceptable.
Sub-surface drainage, Marginal, unacceptable.	Satisfactory, Marginal, Unacceptable.
Sub-surface drainage capability:	Acceptable, Needs Improvement.
describe:	________.
Pavement Material Evaluation	
Surface - Sound condition, deteriorated describe:	________.
Base - Sound condition, deteriorated describe:	________.
Sub-base - Sound condition, deteriorated describe:	________.

Source: AASHTO Design Guide, 1985

Fig. 26.1 The pavement rehabilitation selection process

Table 26.6 Illustrative method for selceting rehabilitation alternatives

	CRITERIA							
	INITIAL COST	DURATION OF CONSTRUCTION	SERVICE LIFE	REPAIRABILITY & MAINTENANCE EFFORT	RIDEABILITY & TRAFFIC ORIENTATION	PROVEN DESIGN IN-STATE CLIMATE	TOTAL COST	RANK
RELATIVE IMPORTANCE	20%	20%	25%	15%	5%	15%	100	
ALTERNATIVE 1	60 / 12	60 / 12	100 / 25	80 / 12	90 / 4.5	100 / 15	80.5	1
ALTERNATIVE 1A	60 / 12	60 / 12	100 / 25	80 / 12	90 / 4.5	100 / 15	80.5	1
ALTERNATIVE 2	60 / 12	60 / 12	70 / 17.5	50 / 7.5	60 / 3	40 / 6	58	5
ALTERNATIVE 2A	60 / 12	60 / 12	70 / 17.5	50 / 7.5	60 / 3	40 / 6	58	5
ALTERNATIVE 3	60 / 12	40 / 8	100 / 25	80 / 12	100 / 5	90 / 13.5	75.5	2
ALTERNATIVE 4	60 / 12	80 / 6	40 / 10	20 / 3	40 / 2	20 / 3	44	8
ALTERNATIVE 5	40 / 8	60 / 12	40 / 10	50 / 7.5	50 / 2.5	30 / 4.5	44.5	7
ALTERNATIVE 6	70 / 14	80 / 16	60 / 12.5	50 / 7.5	80 / 4	40 / 6	60	4
ALTERNATIVE 7	100 / 20	100 / 20	20 / 5	20 / 3	40 / 2	40 / 6	56	6
ALTERNATIVE 8	30 /	60 / 12	100 / 25	100 / 15	100 / 5	30 / 4.5	67.5	3

Source: AASHTO Design Guide 1985

26.7 PRIORITY RANKING FOR PAVEMENT MAINTENANCE BUDGETING AT NETWORK LEVEL

Government road agencies are faced with difficulties in priority allocation for selection of roads from the national road network for annual maintenance programmes. This is also normally constrained by a specific sum available to the road agency. In the absence of systematic criteria for prioriatisation and selection, the decision-makers are subjected to extreme sociopolitical pressure. The factors influencing the selection of roads within a given budget are:

- o traffic level,
- o pavement condition rating, and
- o required budget.

Priority ranking for selection of roads for inclusion in the annual budget programme requires (i) development of a rating scale for the various levels of magnitude of each of the factors; traffic, pavement condition, and budget requirement; (ii) assigning relative importance to each of these three factors, and (iii) comparison of the total score of various roads in the national/state network using the rating and importance previously approved by the competent authority. Tables 26.7 and 26.8 present an example of comparison and ranking of a network of 18 roads. Table 26.7 illustrates a method of priority ranking for budget allocations for road pavement and maintenance.

26.8 HILL ROAD MAINTENANCE MANAGEMENT SYSTEM

A complete hill road maintenance management system includes several sub-systems such as those listed below.

a) Management of Road Corridor within right-of-way.

- Pavement and landslides management system
- Surface and sub-surface drainage management system
- Retaining and breast wall management system
- River training management system
- Bridge management system
- Right of way encroachment management system

b) Management of watershed influencing the road

- Erosion and gully control management system
- Landslide management system
- Developmental activities' management system, e.g., agriculture, irrigation, quarrying, building development

A detailed condition evaluation and management system for each of the sub-systems and a comprehensive hill road maintenance management system need to be evolved for each road agency. Condition evaluation may be done for the network once in three years. However, post-monsoon damage assessment has to be done every year to address emergency maintenance needs and to provide a database for rehabilitation/reconstruction maintenance programmes. Tables 26.9, 26.10 and 26.11 are sample formats for post-monsoon damage assessment of hill roads.

Table 26.7 Illustrative method of priority ranking for budget allocations for road pavement maintenance

S.N.	ROAD	TRAFFIC		PCR		BUDGET LEVEL		ROAD TYPE		OTHERS	RATING SCORE	RANKING
		RELATIVE IMPORTANCE										
		25%		45%		15%		10%		5%		
		A	B	A	B	A	B	A	B			
1	Kakar-Kanepokhari	60	15	50	23	50	8	80	8		53	6
2	Biratnagar-Rangeli	50	13	80	36	50	8	80	8		64	3
3	Rupani-Rajbiraj	50	13	80	36	30	5	80	8		61	4
4	Path-Dhalk-Lahan	60	15	30	14	50	8	100	10		46	10
5	Dhalk-Bhittamod	60	15	30	14	70	11	100	10		49	9
6	Birgunj-Kalaiya	50	13	50	23	70	11	80	8		54	5
7	Chabahil-Sankhu	50	13	30	14	50	8	80	8		42	13
8	Kath-Dakshinkali	50	13	80	36	50	8	80	8		64	3
9	Kath-Lamosangu	60	15	80	36	50	8	80	8		67	2
10	Hetauda-Birgunj	80	20	80	36	70	11	80	8		75	1
11	MRN-Parasi	50	13	80	36	50	8	80	8		64	3
12	Ring Road	60	15	30	14	100	15	80	8		52	8
13	Khaireni-Gorkha	50	13	30	14	70	11	80	8		45	11
14	Bhairawa-Lumbini	50	13	10	5	100	15	80	8		40	14
15	Lagankhel-Godavari	50	13	10	5	100	15	80	8		40	14
16	Butwal-Gorkha	60	15	10	5	100	15	80	8		43	12
17	Bharatpur-Rampur	50	13	30	14	100	15	80	8		49	9
18	Butwal-Sunauli	60	20	30	14	70	11	80	8		52	7

A = Rating out of total score of 100 as per table below
B = A relative importance/100

Table 26.8 Rating scale

TRAFFIC LEVEL		CONDITION RATING		BUDGET LEVELS	
Traffic AADT	Rating	PCR	Rating	Budget Level '000 Rupees	Rating
< 200	50	< 30	100	< 50	100
200-400	60	30-60	80	51-100	70
401-600	70	61-80	30	100-150	50
601-800	80	81-100	10	150-200	30
801-1000	90			>200	0
> 1000	100				

Table 26.9 IDENTIFICATION OF BRIDGE

Report By: ....
Report Date: ....

Highway... Km: .... Region: .... District: ....

Name of River or Bridge .... Bridge Inventory Designation:.........................

DESCRIPTION OF BRIDGE

CONFIGURATION: No. of spans ...... Main span length, each: .... m. Approach span length, each .... m. Roadway with .... m

Foothpath Width: ..... m. No. of footpaths .... Roadway pavement: Bitumen, Concrete, Wood, Other...

SUPER STRUCTURE: Deck type: concrete, wood Girders: steel, concrete, wood, No. .... General Condition: Good, Fair, Poor

SUB-STRUCTURE: Type: concrete, steel brick, wood. Describe piers (if any) ....

Foundation: Type: ....Material: concrete, steel, brick, stone, wood. Depth (if known) .... m

TRAINING WORKS:	Upstream Left	Upstream Right	Downstream Left	Downstream Right
Guide Bunds:				
Facing (gabion, concrete, other)	....	....	....	....
Length X Top Width X Height, m	....	....	....	....
Cut-off or Apron material	....	....	....	....
Other (Describe)	....	....	....	....
Spurs:				
Number and distance from bridge	....	....	....	....
Material (gabions, etc.)	....	....	....	....
Dimension of spur, L x W x H	....	....	....	....
Dimension of apron, L x W x H	....	....	....	....
Other (Describe)	....	....	....	....

DESCRIPTION OF DAMAGE

SUPER STRUCTURE: No. of spans damaged .... Identify by number from N or E ....

Describe damage: ....

SUB-STRUCTURE: Abutments damaged, N/S or E/W. Describe damage: ....

PIERS DAMAGED: Identify by number from N or E .... Describe damage: ....

TRAINING WORKS DAMAGED: Guide Bunds, UL, UR, DL, DR Describe damages: ....

Spurs damaged: No. .... Cu Meters: .... Material: .... Describe damage: ....

Other damages: Describe materials and quantities: ....

Can traffic use bridge? One way: Yes/No Both ways: Yes/No Load limits permitted ..... tonnes. Estimated ADT ....

DAMAGE REPAIR COST ESTIMATE

ITEM	QTY	UNIT	UNIT RS	TOTAL RS
Clear debris	....	CU.M.	....	....
Construct Bypass	....	L.S.	....	....
Temp. Culverts (ϕ)	....	L.M.	....	....
Repair Railings	....	L.S.	....	....
Adjust bearings	....	EACH	....	....
Excavation	....	CU.M.	....	....
Compacted Embankment	....	CU.M.	....	....
Reinf. Concrete	....	CU.M.	....	....
Masonry	....	CU.M.	....	....
Gabions	....	CU.M.	....	....
Other repairs	....	L.S.	....	....

REMARKS: ....
....
....

Source: Adapted from Road Flood Rehabilitation Project (RFRP), Department of Roads (DOR), HMG, Nepal, 1991

Bridge Damage Report Form: Instructions for Use

This form is intended to be used for nearly any kind of damage to any bridge or to the guide bunds, spurs, etc., associated with the bridge. However, it is recognized that there is a lot more information provided on the form than one is likely to need at any one time, and there is no need for the reporter to take the time to complete unneeded items. For example, if there is damage only to a guide bund, there is no need to describe the bridge in detail. Only identification is needed.

HEADINGS: These must be filled out completely in all cases to fully identify the bridge, the cause of damage, date of damage, and the person making the report. The cause and date of the damage are very important if this estimate is likely to be used to support a request for foreign aid. Donor agencies will not usually support maintenance but will support disaster relief as for a flood or an earthquake.

GENERAL: The general information is intended to provide an overall picture of the bridge and its condition. It will help foreign aid donors to decide whether to repair the bridge or replace it in the case of extensive damage.

SUPERSTRUCTURE: Underline or fill in as needed. This information may be already available in a bridge inventory.

SUBSTRUCTURE: Underline or fill in as needed.

FOUNDATION: Complete if possible. It may be impossible to tell what kind of foundations were used without reference to the plans or a bridge inventory.

TRAINING WORKS: Complete only if there is damage to the training works. In a few cases there are more spurs, etc than this form provides space for. In that case, complete what you need to report and list other data at the bottom of the page.

DAMAGES: Fill in as needed to report the damages to various parts of the bridge or the training works. Identify the abutments and training works as left or right bank, facing downstream. Number the immediate piers beginning with 1 at the north, or east end of the bridge, depending on its compass direction. Do not number the abutment as a pair. Number the spurs or other works beginning closest to the bridge and proceeding upstream or downstream on the right or left side. For example, spurs might be 1 UL, 2 UL, 3 UL or 1 DR, 2 DR, etc. If there are more damages than you can list on a single sheet, use an additional sheet, one for each kind of damage. Be sure to note whether traffic can use the bridge, any load restrictions, and the approximate average daily traffic. This will help the Regional or Central Office to decide on a priority for the work.

SKETCH/PICTURES: Always draw a sketch of the damage to scale. Try always to attach pictures but be sure that there is something in your pictures to indicate the scale.

COST ESTIMATES: As with other damage reports, these figures are for planning purposes only and do not need to be precise. They do need to be quick. Complete as well as you can.

REMARKS: Any other useful information

DAMAGE REPORT

ROAD

Table 26.10 IDENTIFICATION

Report By: ....

Report Date: ....

Name of Highway .... From KM ...... to KM ...... Region: .... District: ....

DESCRIPTION OF DAMAGE (Circle pertinent Item)

SKETCH OF SITE (PLAN) Not to Scale

FEATURE DAMAGED	KIND OF DAMAGE
ROADWAY	Destroyed/covered
Pavement	Totally collapsed
Shoulder	Partially collapsed
Embankment	Washed out or breached
Side Drain	Eroded
DRAINAGE	Scoured
Causeway	Undermined
Spillway (cascade)	Other (Describe)
Natural Channel	
Other (describe below)	
CULVERT	
Pipe, .. cm dia, L ... Nos	
Slab/Box .. mLx .. mWx... mH	
Headwall .. mLx .. mWx .. mH	
Wingwall .. mLx .. mWx .. mH	
RETAINING WALL	
....m L ..... m x W ..... m x H	Can traffic use road?
RIVER TRAINING WORKS	One way: Yes/No
Dike or Guide Bund	Both ways: Yes/No
Embankment	Load limits (if any)
Front or Rear Facing	.... tons
Spur or Jetty	Estimated ADT: ....
Other (describe below)	Vehicles
MISCELLANEOUS	
Signs	
Guide Posts	
Km Post	
Railing	
Other (describe below)	

DESCRIPTION OF RECOMMENDED REPAIR WORK

TEMPORARY EMERGENCY REPAIR WORK (Describe in detail)

....
....
....
....

PERMANENT REPAIR WORK (Describe in detail)

....
....
....
....

DAMAGE REPAIR COST ESTIMATE

TEMPORARY EMERGENCY REPAIR WORK

ITEM	QTY	UNIT	UNIT RS	TOTAL RS
Clear debris	......	CU.M.	....	....
Construct Bypass	......	L.S.	....	....
Temp. Culverts (ϕ)	......	L.M.	....	....
Excavation	......	CU.M.	....	....
Masonry	......	CU.M.	....	....
Gabions	......	CU.M.	....	....
Other Repairs				....

ITEM	QTY	UNIT	UNIT RS	TOTAL RS
Clear debris	....	CU.M.	....	....
Culverts (ϕ)	....	L.M.	....	....
Excavation	....	CU.M.	....	....
Compacted Embankment	....	CU.M.	....	....
Reinf. Concrete	....	CU.M.	....	....
Masonry	....	CU.M.	....	....
Gabions	....	CU.M.	....	....
Other Repairs				....

General Remarks ....
....
March 1991 ....

Source: Adopted from RFRP, DOR, HMG Nepal, 1991

Road Damage Report Form: Instructions for Use

PURPOSE: The purpose of this worksheet is to provide damage estimators with a simple form for quickly estimating the cost of replacing or repairing road features damaged or destroyed by floods, landslides, or other events.

GENERAL: This form is intended to be site-specific. This means that each sheet used should cover only one particular location along a road. If two or more kinds of damage occur at that place, one sheet should be used for each kind of damage in order to prevent confusion in the quantities or costs involved. Where features of the road are completely destroyed, the estimator must refer to the maintenance feature inventory to find out what is missing and what needs to be replaced. This form is not intended for large items, such as bridges, which are too complex to be handled in this simple format. One should refer to the bridge inventory, bridge plans, and bridge damage report form to estimate repair costs. Slab or box culverts are included in this form.

All prices used in this form are intended to be complete in place. For damage estimation it is not necessary to precisely price every possible item. The figures are to be used only for budgeting and programming processes. Figures should be reasonably accurate, but speed in compiling the estimate is usually more important than exact detail. Each District Engineer should have, or develop, basic unit costs through averaging of recent bid prices for these items in his district and have these available for estimating purposes. Individual worksheets may consider overhead factors such as design, contract administration, profit, contingencies, etc. but be sure that these are not already covered on the item prices.

Headings:

1) The name of the Highway, Region, and District are self-explanatory and could be preprinted or rubber stamped.

2) The kilometre should be as exact as possible, determined by vehicle odometer from the nearest kilometre post, or other means. Where damage is in one place, for example, a culvert washout, only one kilometre should be used. Where a larger feature is involved the beginning and end of the damage area should be shown to give an impression of the size of the damage.

3) The maintenance feature, name, and number should be taken from the maintenance inventory. If these are not available use descriptive terms such as culvert, retaining wall, dike, spur, etc. This form is intended to also apply to off-road features for which the DOR is responsible, even if these are a kilometre or more away from the road. Damages to river training works should be reported on the bridge damage report form.

4) Describe the cause of damage, such as flood, landslide, heavy rain, etc.

5) Give the date of damage. Do not repeat damage reports as this will cause confusion. Correctly identifying the cause and date of the event may make it easier to justify donor funds.

6) Date of the damage report and the name of the person making the report.

Dimensions: All dimensions are in metres, length x width x height (depth or thickness). Where damages are irregular in shape, the estimator will have to do his best to determine the volume.

Feature Damaged: In this section simply underline or circle the feature damaged and complete the dimensions for culverts. It is intended that a separate sheet will be used for each damage, except for very small things such as signs. Therefore, if a culvert is washed out you would have one sheet for the culvert and another for the roadway over the culvert. You should not underline unrelated items.

Materials: The materials underlined should be those of which the damaged feature was built. Normally, roadway damage might include soft or hard soil and asphalt pavement, etc.

Kind of Damage: This will help the person receiving the report to understand what has happened.

Salvageable Materials: List materials that can be re-used and make proper allowances in determining the estimated costs.

Notes: Enter here any further information that will help to explain the damage.

Describe Temporary Repairs: If anything was done on a temporary basis to get traffic through or around the site, describe and estimate the cost. If you need more space go to the 'remarks'' block at the bottom of the page. Donors may include the cost of emergency repairs in their contribution.

Sketch: Except for very minor damages, such as signs, always make a drawing to some scale with dimensions showing the damage in plan view or in elevation, whichever would be the most descriptive.

Pictures: In addition to the drawing, always attach pictures. The photographer should always write an identification on each picture, and, where the scale is not apparent, include something in each picture which will indicate the approximate size of the feature.

Estimates: This block is intended to help provide systematic damage estimates. Each item should be a regular DOR work item with the appropriate material, unit, and unit cost following. Be as brief as possible but provide enough information so that someone else reading your report will be able to follow what you did.

LANDSLIDE

Table 26.11 IDENTIFICATION

Report By: ....

Report Date: ....

Name of Highway .... Approximate KM .... Region: .... District: ....

DESCRIPTION OF DAMAGE (Circle pertinent item)

FEATURE DAMAGED

ROADWAY
- Pavement
- Embankment
- Side Drain

DRAINAGE
- Spillway (cascade)
- Natural Channel
- Other (describe below)

CULVERT
- Pipe, .. cm dia, L ... Nos

RETAINING WALL
- ....m L.... m x w .... m x H

KIND OF DAMAGE
- Destroyed
- Covered
- Totally collapsed
- Partially collapsed
- Washed out or breached
- Eroded
- Scoured
- Undermined
- Other (describe)
- Can traffic use road?
- One way: Yes/No
- Both ways: Yes/No

DESCRIPTION OF RECOMMENDED REPAIR WORK

TEMPORARY EMERGENCY REPAIR WORK (Describe in detail)

....

Volume calculation of material to be removed:

....

PERMANENT REPAIR WORK (Describe in detail)

....

Volume calculation of material to be removed:

....

DAMAGE REPAIR COST ESTIMATE

TEMPORARY EMERGENCY REPAIR WORK

ITEM	QTY	UNIT	UNIT RS	TOTAL RS
Clear debris	......	CU.M.	....	....
Construct Bypass	......	L.S.	....	....
Temp. Culverts (ϕ)	......	L.M.	....	....
Excavation	......	CU.M.	....	....
Masonry	......	CU.M.	....	....
Gabions	......	CU.M.	....	....
Temp. drains	......	L.M.	....	....

Other Repairs ....

ITEM	QTY	UNIT	UNIT RS	TOTAL RS
Clear debris	....	CU.M.	....	....
Culverts (ϕ)	....	L.M.	....	....
Excavation	....	CU.M.	....	....
Compacted Embankment		CU.M.	....	....
Reinf. Concrete	....	CU.M.	....	....
Gabion	....	CU.M.	....	....
Masonry	....	L.M.	....	....
Surface drain	....	L.M.	....	....
Subsurface drain	....	CU.H.	....	....
Horizontal drain	....	L.M.	....	....
Rock bolt	....	M.	....	....
Vegetation	....	SQ.M.	....	....
Plantation	....	Nos.	....	....

Other Repairs ....

General Remarks ....

....

March 1991..

Source: Adopted from RFRP, DOR, HMG Nepal, 1991

Instructions for Users: Landslide Damage Report

PURPOSE: The purpose of this report is to provide the District, Regional, and Central offices with a quick estimate of the damages at a landslide. Speed is more important than extreme accuracy because the data most likely will be used for budgeting rather than final costing. Therefore, you should not try to get precise data. Quick data is better than no data. If you have survey equipment, fine, but if you do not, pace the distances and estimate heights.

SELECT SLIDE TYPE: Selection of the type of slide is important because some are much more expensive to repair than others. For example, a Type I slide simply covers the road without seriously damaging it. The principal work will be to clear away the debris and reopen clogged side drains and culverts. You can see the road surface on both sides of the slide. Look at the debris pile on the road. If you can visualise that the debris pile is mostly above equal to or bigger than the scar above the road, this probably is a Type I slide.

Type II is harder to repair and therefore more expensive. You may see a fragment of the old pavement or old road surface in the debris and sometimes these are not badly broken up. It will very often look as though there is not enough material to refill the scar above the elevation of the roadway and there will sometimes be a noticeable bulge in the debris slope below the road which may indicate the area of the slip plane. There may have been a retaining wall before the slide which is visibly moved or damaged at the edge of the slide.

Type III offers no problems of recognition. All of the slide is in or below the road and easily visible. Be sure you include slides that do not damage the road at this time but are threatening it because they are close to the edge of the shoulder or pavement and could expand at any time.

DATA: Quite a.lot of data is required but you should be able to accumulate this in an hour or two in the field. You can assume that a slide is roughly shaped like a sector of a circle both in length and width and by making a few measurements and some sketches, roughly to scale, you can estimate the depth and volume sufficiently well for this purpose. The maximum length and width should be taken and these may not have anything to do with either the centre of the slide or the roadside. You may have to make some intelligent guesses as to the location of the slip plane below the road since it will be covered by debris that may run on well down the hill, but these do not mean much unless they do some damage to houses, ditches, or other roads below.

VOLUME OF DEBRIS REMOVAL: For Type I, this is easy. Simply scale in the road elevation and select average dimensions for the debris pile. On the cut side you will have to remove some extra material to keep it from falling down later. Base your estimate on a 2H:1V side slope and divide the roadway prism into a few rectangles or triangles for ease of estimation.

In order to reconstruct a Type II or III slide, you must remove the debris down to the slip plane, which will be easy to recognise when you get there. Then you must break up the slip plane and establish flat benches to support the new compacted embankment. On the data sheet sketches, estimate the area of the small triangles shown below the slip plane. Use this for the average end area multiplied by the width of the slide (L max) and you will get a figure for estimating, which ought to be on the conservative side.

All debris removal ought to be at soft soil rate unless there is a lot of rock. Include an estimate for haul to a safe place. DO NOT sidecast it on to the toe of the fill. That may cause another slide below the road.

DRAINAGE: Estimate the amount of side drainage to be cleaned or rebuilt. If culverts have been plugged or destroyed, you may have to go to maintenance feature inventories or other records to find out what was there. You should build a new cross culvert 20 or 30 metres beyond the slide on the upgrade side so that you do not have to transport ditchwater across the slide area, risking new movement. Consider also causeways, cascades, spillways, etc. which might have been ruined or might be needed.

WALLS: There may have been walls on either side of the road which have been destroyed or damaged. In extreme cases, you may have to search records to find out and make estimates for replacement.

COST ESTIMATES: Field data should give a listing of items and quantities. The District Office should be able to provide unit prices. For this purpose all prices should be as simple as possible and listed as complete, finished in place. For example, concrete might be priced by the cubic metre, including cement, aggregate, steel, formwork, and labour, all in one unit price. A slab culvert might be priced on a square metre basis and so on. These estimates are not meant to be precise. Total the estimate for each location at the bottom of the sheet. If surveys, contingencies, and contract taxes were included in your unit prices, do not repeat them.