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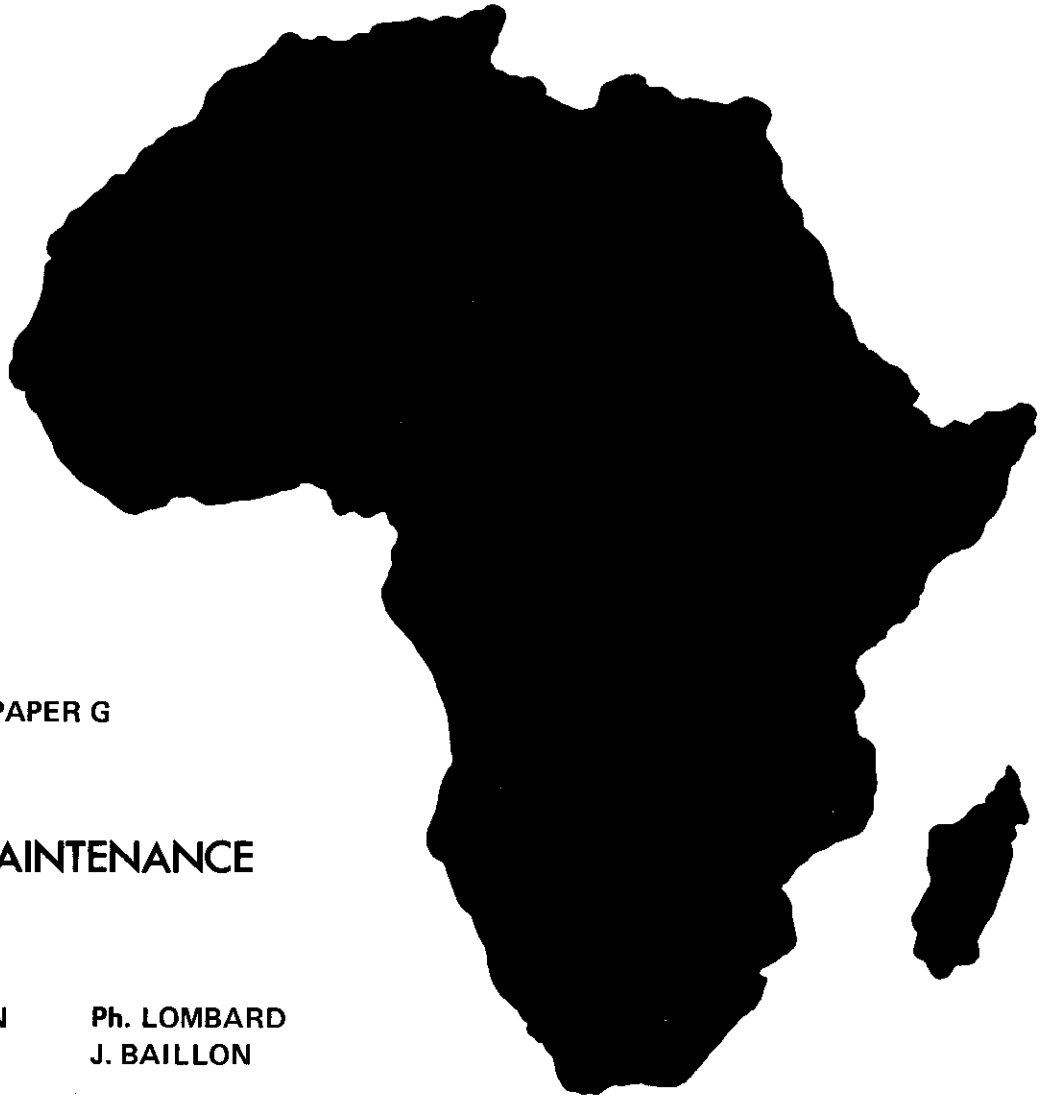

PAPER G

ROAD MAINTENANCE

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ROAD MAINTENANCE

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PAPER G - ROAD MAINTENANCE

ABSTRACT

Road maintenance varies greatly between different authorities in its scope, expenditure and standard of performance. Decisions on maintenance are too often made on subjective judgements and there is an urgent need for better systems for assessin g road conditions. Meanwhile organisation and training should be improved and a more vigorous maintenance policy adopted.

Earth and gravel roads are generally classed as unimproved, intermedate and improved or engineered gravel roads. The chief maintenance needs of these roads are discussed and rates of formation of corrugations and gravel-loss given for different countries. Different grading techniques are compared. Tracks leave special maintenance problems because they sometimes carry heavy traffic at peak periods despite minimal construction. Regravelling work should follow careful study of materials, water sources and climate, using rains to assist compaction where possible.

Base material for bitumen surfaced roads, needs to be more carefully selected than for gravel roads. Most kinds of bituminous road share the same problems of cracking, potholing, ravelling etc. The causes and remedial measures for these are discussed. Parameters are suggested for further work aimed at developing a method for assessing maintenance needs.

To be effective in keeping roads to an acceptable standard, maintenance organisation should be more sophisticated. With better definition of tasks all relevant data could be collected and processed to reveal areas of high and low efficiency. Data processing should be carried out by special units with the aim of improving methods, reducing costs and providing a higher standard of maintenance. Training schemes more relevant to technical and human needs should be developed.

True costs of road maintenance are often difficult to assess because of inconsistency in accounting and poor records. This paper defines the necessary chargeheads and categories of expenditure. Approximate costs of different operations in relation to traffic are quoted for different countries and an approach suggested for relating maintenance costs of bituminous roads to numbers of "standard axles".

Recommendations include:

- more test-sections covering a range of different environments

- more sophisticated information and data-processing systems

- more vigorous programmes of relevant training

- adoption of objective standards of condition and performance.

1. INTRODUCTION

1.1 Definition of road maintenance

The term 'maintenance' may be interpreted differently by different road authorities and is largely influenced by internal policies and financing. Structural improvements and provision of road furniture and amenities are sometimes included, while elsewhere 'maintenance' means the bare minimum work needed to keep the road open. In this paper we have taken maintenance to mean those activities required simply to preserve the road from deterioration.

1.2 Administration

The administration of road maintenance is as complex as the activities concerned with it. Rural roads, both main and feeder are usually the responsibility of central government, while urban roads are the responsibility of urban authorities. The situation is confused by the existence in some places of local government and community-financed maintenance schemes and by roads looked after entirely from private funds. The actual work may be carried out directly by one of the authorities mentioned for their own roads or, as agent, for another's. In practice, most works are carried out by the appropriate Government department but additional works are undertaken by contract.

1.3 Differences in standards

The wide differences in maintenance standards and expenditures are due not only to environmental factors but also to human and organisational influences. Studies in this field are rendered particularly difficult by the inconsistencies in maintenance accounting. For instance records of expenditure frequently include large sums under a 'miscellaneous and general maintenance' heading which fails to identify the various maintenance costs. In the absence of more reliable methods for allocating funds, decisions are usually made on the basis of 'the engineer's judgement' and the attitude of the authority responsible.

As an example of the wide divergence of maintenance expenditure reported from one area to another, the annual resurfacing allocations for Class I roads in Britain in 1970 were as follows: (B1)

Rural roads £170 to £1670 per mile or 3p to 140p per 1000 veh. miles.
Urban roads £80 to £2680 per mile or 2p to 80p per 1000 veh. miles

These wide discrepancies although due in part to differences in accounting clearly indicate the great effect of subjective judgement in decisions concerning road maintenance.

1.4 The need for information

There is considerable disagreement on the status of maintenance. There are cases, regrettably few, where maintenance activities are regarded as vital in protecting the highway investment. More often, maintenance activities are under-financed, make little use of research, and are under-mechanised. Available resources are often devoted to purposes with a more immediate public appeal, such as medicine, education, housing or even road improvement. There is clearly a need for research to establish economic levels of maintenance and to define the methods of achieving these levels.

1.5 The need for defined standards

Engineering standards concerning the manner and frequency of maintenance operations in various situations have yet to be defined. Those that do exist are so varied that the adoption of properly defined standards can only be beneficial. Such standards would make possible a logical division of funds according to the needs of each area or road and, moreover, would enable comparisons to be made of work outputs by different teams or different methods.

The three chief needs are:

(1) defined maintenance standards for each type and situation of road
(2) a simple system for assessing the condition of a road and its need for maintenance
(3) realistic work-output values for men, methods and machines.

Studies carried out in Britain have been described in a comprehensive report[B1] which makes recommendations to meet these needs and it is possible that this might also be a useful basis for standards in Africa. Data from a four-year highway design study, now being assessed, should yield enough information on surface conditions for an initial set of standards to be formulated.

1.6 The present position

Meanwhile much can be done to make operations more effective by improvements in existing techniques. To achieve this it is essential to keep a close watch on maintenance work and record accurately what is done, what materials are used and what are the results. Organisation is dealt with in considerable detail in this paper because of the great importance of obtaining data of this sort; this is vital if methods are to be improved and the best materials identified.

A major purpose of this paper is to define and discuss the problems of unsurfaced and surfaced roads and the roles of training and organisation. Also, above all, to stress the need for a vigorous and progressive approach.

2. MAINTENANCE OF UNSURFACED ROADS

2.1 Types of unsurfaced road

Unsurfaced roads include two main categories:

a) Unimproved roads which are simply tracks across the natural soil with, at best, a little selected material deposited at the lowest places, but with little attention to drainage and river crossings, often impassable in the wet season.

b) Improved gravel roads designed to definite engineering standards of material and geometry which should permit the drainage of 10-year floods and vehicle speeds of 80-100 km/hr.

An intermediate category may be identified where a track has evolved to a higher standard, generally without formal design.

2.2 Routine maintenance techniques for unsurfaced roads

2.2.1 Spot patching. The purpose of spot patching is to prevent, by regular and frequent attention, the deterioration of the road. The work is normally limited to repair of surface damage but sometimes includes the provision of reinstatement material, removal of sand drifts, bush encroachments, etc.

Spot patching is a 'mixed maintenance' task, necessarily involving both plant and labour-intensive activities, and responds well to local improvements in method and organisation. Thus, in some African countries, teams consist of about 20 labourers supported by 3 or 4 lorries and digger/loaders, covering 300 km of road, while others, including Mali, Niger and Upper Volta, operate smaller teams with only 10 men and a truck, covering up to 70 km. Responsibility for provision and laying of reinstatement materials is sometimes divided between teams totally independent of one another.

2.2.2 Longitudinal reshaping Although not fully understood, the formation of corrugations in earth and gravel roads is probably due to two main factors: reduction of cohesion due to drying or loss of fines, and the pushing effect of traffic. The parameters involved include:

looseness of surface material,
the presence of a fine gravel fraction (5mm - 15mm)
humidity,
traffic speed, weight and intensity.

Remedial measures take two forms:

For friable materials, dragging with wire brushes, heavy chains, heavy rubber tyres or weighted wooden frames fitted with grader blades is generally effective;

For more plastic materials in a damp climate or where dragging has been too long delayed, corrugations may be very hard and grading is necessary. This has the disadvantage that, due to the depth of operation, a loose surface is left over the whole road.

The frequency of these operations depends on the speed of wave formation. Appendix 1 gives data from Senegal and Niger relating corrugation formation to daily traffic volumes.

2.2.3 Cross-shaping of the roadway Operations to remove corrugations are not usually effective in restoring the lateral profile of a road and periodic deep grading is necessary to redistribute material and improve run-off. This may be performed with graders operating singly or in echelon.

In the Ivory Coast, grader teams generally consist of two heavy graders and one or two light graders depending on road width. These are operated in three different ways known as the 'fill method', 'cut method' and mixed profile method', and are depicted in Appendix 2. Their advantages and disadvantages are summarised below:

	ADVANTAGES	DISADVANTAGES
FILL METHOD	Negligible losses in surface material. Drainage improved.	The need to maintain stock-piles of selected material. The difficulty of achieving correct moisture content for compaction of fill material. Danger of excessive camber.
CUT METHOD	Easy to perform No need for additional materials or water bowsers.	Loss of surface material. Loss of camber Poor run-off.
MIXED PROFILE METHOD	Only slight loss of surface materials	Tendency towards loss of camber and imperfect drainage

A method adopted in Zambia, which uses only one machine and has the chief characteristics of the Mixed Profile method, is also shown in Appendix 2.

2.2.4 Ditch maintenance Maintenance of the carriageway will only be effective if proper attention is given to ditches and turnouts. This work is made easier if the road has been constructed with wide sloping shoulders formed continuously with the verges and which can be kept clear by grader. Often this is impossible, however, as in the case of old roads or roads with limited reserve, or where good turf exists which is to be preserved as erosion protection. Much of the work must be performed manually in any case, particularly around culverts or near masonry structures and erosion-control devices.

2.2.5 Maintenance of structures and road signs This work includes clearing of culverts and maintenance of the associated masonry, construction of gabions or dry-stone walls in highly erodable sections, painting of bridges, placing of protective rock breastwork around bridge structures and replacement of painting of road signs.

This maintenance should be based on a detailed programme prepared after an inspection of the structures at the end of the wet season.

2.2.6 Control of trees and scrub Trees and scrub should be cleared well back from the carriageway so that the wind and sun can have full play in drying the road surface. In heavily-wooded country, it is desirable for trees to be cleared for a distance from the road equal to the average height of the tree-cover. In the tropics, on roads with North-South orientation, it is an advantage to increase the clearing distance up to $1\frac{1}{2}$ times the height of the trees.

2.2.7 Maintenance of verges Verge maintenance involves filling erosion gullies and ruts caused by traffic, as well as grass-cutting.

While the repair of gullies and ruts is often entrusted to the spot-patching team, grass-cutting is usually carried out separately. Grass-cutting is an important operation aimed at isolating the road from encroachment by roots and scrub and improving drainage and visibility. Grass-control can be maintained by hand-mowing, burning or by machine; where erosion is a problem, burning is better avoided.

In equatorial regions, clearing of verges must be performed three or four times a year. In arid areas once a year is probably enough.

2.3 Special problems of tracks

Jeep-tracks frequently show special characteristics which influence their maintenance considerably. Unlike engineered roads it is not usually possible to establish a maintenance structure based on a geographical distribution of labour. Also, their use fluctuates with local agricultural needs and, while one may be needed throughout the year, another may have intense use for a short period only. Under these conditions the organisation of jeep-track maintenance calls for very careful planning, particularly with regard to the possible re-use elsewhere of excess material collected during peak working periods.

Routine maintenance operations are generally limited to grading and spot-patching. Occasionally, however, a jeep-track may be improved to the 'Intermediate' category by the work of an improvement maintenance team whose main tasks are to:

- raise low areas above water level
- improve drainage
- build small structures
- lay a wearing course
- improve road geometry

etc.

This kind of maintenance is properly regarded as a valuable investment and is usually the responsibility of special teams.

2.4 Special problems of gravel roads

Regular regravelling with selected material is the operation which chiefly distinguishes gravel roads from other classes of non-bituminous road, the aim being to provide a wearing course which will withstand the ravages of traffic and which is not too difficult to maintain.

The operation has to be carried out at regular, but relatively long, intervals, generally between 3 and 10 years, the interval being a function of traffic intensity, climate, drainage and the quality of materials and workmanship. The normal rate of loss of gravel as a function of average daily traffic for three areas in West Africa is as follows:

Cameroon		Niger		Ivory Coast	
Vehicles/day	Wear cm/yr	Vehicles/day	Wear cm/yr	Vehicles/day	Wear cm/yr
0 - 10	0.75	60	1.50	50 - 100	2.0
10 - 20	1.30	60 - 80	1.80	100 - 200	2.5
20 - 50	1.75	80 - 100	2.00	200	3.0
50 - 100	2.25	100 - 120	2.10		
100 - 200	2.75	120 - 150	2.50		
200 - 400	3.50	150 - 200	2.70		
400 - 600	4.00	200 - 300	3.00		
		300	3.50		

On average 200 vehicles per day brought a loss of about 3 cm gravel per year but the relationship is non-linear and the greater the traffic intensity the greater is the rate of increase of gravel loss. Two factors could give this effect: firstly weathering and secondly the higher standard of maintenance and hence higher traffic speeds on the more heavily-trafficked roads. Regravelling is generally performed in layers of about 15 cm.

2.4.1 Regravelling organisation Regravelling should be carried out when the thickness of gravel surfacing has worn down to about 5 or 6 cm. Further degradation may expose the road base in places, with the risk of structural damage.

Before starting operations, a technical study should be carried out to establish the quantities of material required and, using all available survey methods, the best locations for borrow-pits to reduce transportation to a minimum. A flow-chart for these operations is shown in Appendix 3A. The study should also cover the availability of water for compaction since this may dictate the method to be adopted. In Niger, for instance, a two-phase regime was followed, with normal maintenance and supply of materials during the dry season, and regravelling, shaping and compaction during the rains, thus eliminating the considerable expense of importing water.

A final plan should then be made taking into account the availability of equipment, capacities, deadlines and technical difficulties identified during a study of the transportation problems involved. (See flow chart in Appendix 3B).

In the interests of good conpaction, the thickness of gravel to be laid must not exceed 15 to 20cm. Thinner resurfacing may be justifiable where traffic is light (30 to 40 vehicles/day) provided this does not lead to further regravelling within 7 or 8 years.

3. MAINTENANCE OF BITUMEN SURFACED ROADS

Bituminous roads represent the next stage in development beyond the engineered gravel road described in Section 2. The geometry of the road, its design speed, earthworks and structures might be the same but, with the addition of a bituminous surface, an entirely different set of principles apply. Most important, with the acquisition of bituminous surfacing, a road becomes a far greater responsibility requiring new skills, new equipment and an organisation geared for rapid and decisive action if the benefits of bituminisation are to be preserved. Surfaced roads permit less tolerance in selection of materials and it is to be noted that before a decision is made to upgrade a road to bituminous standard careful check should be made that the base material has the appropriate properties[B2].

The term 'bituminous' includes a variety of different construction methods and materials which, for maintenance purposes, may be divided into five main types of base and three types of surfacing. (Concrete is not dealt with in this paper.)

3.1 Bases

The commonest type of base is still unstabilised gravel which depends for its strength chiefly upon internal friction. In the conditions existing below a sealed pavement this demands careful quality control, particularly regarding grading and plasticity. However, much of this traditional construction has now given way to material containing small percentages of cement or lime which can impart great strength to a range of soil types and avoid failures due to accidental inclusion of inferior materials.

Bituminous stabilisation is only effective with clean dry sands and is therefore virtually confined to desert or semi-desert areas. The bitumen-stabilised material remains fairly soft and the durability of the base depends upon its great flexibility under load or shock.

Crushed rock makes up the fourth group of base types. This may be crusher-run containing all sizes from 75 mm downwards or single-size stone with added fines. All depend purely upon mechanical interlock for their strength and load-spreading properties.

3.2 Surfacings

'Surface dressing' by which a film of bitumen or bitumen emulsion is dressed with stone chippings is the simplest and yet one of the most useful forms of bituminous surface. It adds practically nothing to the strength of the base but waterproofs it and forms a good running surface. A variation of this used in a few places is 'slurry seal' which is a suspension of mineral fines in bituminous emulsion laid cold. When set, it effectively waterproofs the base but does little to correct irregularity and shock, and is said to give poor skid resistance when wet.

Bituminous premix is the third main division and embraces a range of mixtures of bitumen, stone and mineral fines generally mixed and laid hot. The major groups are rolled asphalt and bitumen macadam;[B3, B4,] fine cold asphalt[B4] is sometimes used for rapid patching in urban situations.

Emulsions are often used for small-scale work where hot-mix plant is not available and speed is essential.

Bituminous premixes must be laid at least 35 mm thick and they therefore add appreciably to the load-bearing properties of the road. These materials are commonly employed to correct surface deformation but are generally used over the whole carriageway only on roads of the highest category. They give very good riding qualities and protection of the base against attrition or shock but are expensive and demand a high standard of maintenance.

The chief purposes of bituminous surfacing are to:

(a) provide smooth riding conditions
(b) protect pavement layers and subgrade against loss of strength through water ingress
(c) reduce evaporation, which can cause damage by soil shrinkage
(d) protect base material from impact or abrasion.

In common with most of the other maintenance operations including work on verges ditches, culverts etc., function (a) is the primary consideration with which all the others are ultimately concerned.

3.3 The problems of a bituminous road

From the moment a bituminous road comes into service it is under attack and the maintenance engineer must work hard to keep the forces of disorder under control. Ground water movements, rain, weathering and erosion, as well as the more obvious assaults of traffic cause a variety of troubles but the one most often leading to rapid destruction of the road is cracking.

3.3.1 Cracking This occurs in several different forms:

a) 'Alligator' cracking. This appears as a pattern of fairly closely-spaced cracks running in all directions, is often associated with deformation and generally indicates base failure.

b) Longitudinal cracking, type 1 Longitudinal cracks in stabilised construction along the edges of construction lanes. This is due to faulty union between adjacent lanes caused by, for example, delay in following up with the next strip, insufficient cut-in, incomplete coverage by the stabiliser spreader or rollers. A very similar type of cracking can occur in non-stabilised roads when granular bases are laid and compacted in strips. In this case the road near the cracks often sounds hollow when struck.

c) Longitudinal cracking, type 2 Longitudinal cracking in wheel-tracks generally caused by settlement of inadequately compacted base or deformation of subgrade.

d) Longitudinal cracking, type 3. Severe cracking beginning near the verge and progressing inwards. This is common on expansive clays and is due to seasonal shrinkage of the subgrade near the shoulders causing rupture of the construction.

e) Longitudinal cracking, type 4. Severe cracking extending to the centre of the carriageway on embankments. This is due to settlement and spreading of porly compacted earthworks. (Plate 1).

f) Lateral cracking. Usually fairly widely spaced, this indicates base shrinkage. It can be associated with both stabilised and unstabilised materials, especially if these contain plastic fines.

g) Block-cracking of stabilised base This occurs when a relatively inflexible stabilised base has inadequate sub-base support or is subjected to excessive wheel-loads and behaves like a weak concrete. (Plate 2). Complete disintegration of the base sometimes follows.

3.3.2 Pot-holes Neglect of almost any damage to a bituminous surface, however trivial, usually leads to pot-holing which can develop with astonishing speed. It occurs when particles exposed by a rupture are torn away by vehicles' wheels causing impacts of increasing severity on an increasing area and depth of construction. Pot-hole formation is especially rapid in wet weather when bituminous coatings are more likely to strip and base materials to be weakened.

3.3.3 Edge erosion This is caused by vehicles running off the surface on to the shoulder and it is aggravated by standing water. It is one of several serious faults associated with single bituminised strips on two-way trafficked roads, nowadays regarded as poor economy. Fretting of the construction itself follows the loss of lateral support at the shoulder.

3.3.4 Loss of chippings. This may be due to excessive speed soon after surface dressing or to poor workmanship or materials. Possible reasons include wrong sized or dusty chippings and poor binder distribution.

3.3.5 Fatting-up Excessive bitumen in the surfacing appears between the chippings and partly or completely covers them. It adheres to vehicles' tyres, causes loss of surface texture and makes a slippery wet-weather surface. Fatting up and loss of chippings may sometimes be confused.

3.4 Types of maintenance

When considering the provision to be made for preserving the road structure it is useful to group maintenance operations under three main headings:

routine: generally small works not much affected by traffic
recurrent: repair operations of a frequency which is greatly affected by traffic.
periodic: large-scale works carried out very infrequently.

3.4.1 Routine maintenance operations These include grass cutting, clearance of ditches and culverts etc. and are carried out as described for gravel roads.

3.4.2 Recurrent maintenance operations

a) Crack repairs Most of the repair works needed for the troubles described in para 3.3 come into this category but cracking is probably the biggest concern. Most kinds of cracking can be dealt with in their early stages by patching or applying an ordinary seal to limited areas and it is obviously desirable that this should be done without undue delay. However, with the limited resources of works organisations it is usually only possible to carry out repairs in rotation, but some situations do demand speedy action. In a typical emergency the subgrade or base are known to be vulnerable to water and, as well as cracking, deformation which may cause ponding is present also. In this situation a few days' delay can be catastrophic if heavy vehicles are using the road. Small-scale work which cannot wait until the next routine surface dressing must usually be carried out by hand. Typical procedure is as follows:

Method 1. Clean and slightly dampen the area; apply bituminous emulsion at about 2 to 2.5 l/m^2 using hand spray or sprinkler cans, blind with clean chippings which may be slightly damp.

Method 2. Clean the area. When dry, apply hot cut-back bitumen at about 1 to 1.2 l/m^2 using hand sprays as before, blind with clean dry chippings.

Method 3. Clean and slightly dampen the area; apply a slurry seal of bituminous emulsion and quarry fines mixed to a creamy consistency using rubber squeegees.

Where severe cracking has occurred there may be loose surface material adjacent to the cracks which must be scraped away before spraying. In the case of very wide cracks, say more than 5mm, these should be opened up using a pneumatic drill with chisel blade and fine cold asphalt tamped in first.

Sealing the cracks is the first concern but in many cases that is only half the story. Where shrinkage of expansive clays has been the cause the shoulders should be given some protection, perhaps by a bituminous film or a layer of gravel containing

plastic fines. Where severe alligator cracking has occurred, the base must be reconstructed using materials which can take traffic immediately, eg block stone and/or graded crushed rock. Deformation should be corrected using bituminous premix, crushed stone with bitumen grouting (hot bitumen or cold emulsion) or simply crushed rock where a considerable depth is involved, in each case with a surface seal to match the original. Basic causes like poor drainage or weak construction should be investigated and corrected as soon as possible.

b) Potholes These can be treated in several ways depending upon the road type and the material available, but the following points should be observed:

(1) the hole is cut to give a good key for fill material,
(2) fill material is compacted flush with the road surface,
(3) the patch is sealed against water and dressed to match the original surface as far as possible.

Fill material must generally be able to take traffic immediately without deformation or damage. This rules out most natural gravels (except for gravel roads with low wheel-loadings) and stabilised soil unless laid to the full depth of the base and protected during the curing period.

For cement and lime-treated roads hot-mix bitumen macadam tamped into well-primed holes and surface dressed is probably the best treatment. This can be made at a central mixing plant or in a mobile hot-mix plant. If a central mixing plant is used the mix must be of a type which will remain workable for several hours. Details of this method (B5) are given in Appendix 4.

Mixes containing bituminous emulsion are particularly useful in remote areas but, because mixing is very dependent upon quality of aggregate, local experiments should be performed before large-scale work is commenced. A method recommended in Kenya, using bituminous emulsion, is given in Appendix 5.

Potholes in non-stabilised roads can generally be filled successfully using either bitumen macadam as above or with material similar to the base itself.

c) Edge erosion Repairs to eroded edges of bituminous roads can only be done with hand tools to compact material back against the exposed construction. Dumps of material at frequent intervals, generally local gravel, are desirable for this purpose, particularly if the shoulder material is itself inferior.

d) Fatting up Excessive bitumen in surfacing forming a free layer on the surface, has no real cure except burning off and applying fresh surfacing. However sanding at intervals will give relief.

3.4.3 Periodic maintenance operations For bituminous roads surface dressing is the chief operation under this head. This is the subject of a separate paper (Paper C).

3.5 Maintenance assessment of bituminous roads

Assessment of the need for maintenance is still a matter of personal judgement in most African countries but there is an obvious need for recognised standards particularly in the areas of surface dressing, patching and reconstruction. Further study of data now becoming available will be necessary before firm proposals can be made but the factors to be identified in drawing up standards are fairly clear. The following are suggested:

Surface dressing

(a) crazing, imperviousness to water
(b) % area of deterioration
(c) skidding resistance (sideways force coefficient)

Patching

(a) danger from pot-holes
(b) depth of standing water after rain
(c) % area of deterioration
(d) amount of edge erosion

Reconstruction

(a) permanent deformation
(b) loss of aggregate, fine crazing, general deterioration
(c) surface irregularity indicated by bump integrator
(d) camber.

A further important factor concerned with the preservation of the complete road structure is deflection beam reading, excessive values indicating the need for base strengthening. This problem is covered in a separate paper (Paper B).

4. MAINTENANCE ORGANISATION

Highway maintenance operations cannot be carried out effectively without resources, assigned objectives and precise guidelines.

4.1 The need for maintenance organisation

Highway maintenance organisation is required for

- determining costs
- improving techniques
- checking the efficiency of methods
- supervising the utilisation of resources
- establishing national budgets
- monitoring the evolution of the road network in relation to traffic
- improving highways.

An organisation is needed capable of collecting all relevant data on quantities, qualities, prices, output, skilled manpower, plant etc which will help achieve these objectives.

4.2 Collection, distribution and processing of highway maintenance data

4.2.1 Description of roads and list of tasks The first requirement for logical maintenance planning is a schedule of roads by location, description and classification. This schedule, which is generally a linear diagram detailing individual road sections, should contain all information relevant to maintenance planning, including:

- village names
- benchmark locations
- structures
- roadway width
- roadway construction
- borrow pits
- water points
- road signs
- newly completed works (location, nature, date)
- average daily traffic.

To avoid confusion in specifying tasks a precise list of operations should be established. Appendix 6 shows an example for earth roads in Mali.

4.2.2 Collection and distribution of data. A careful record of operations is necessary if the impact of maintenance work on each road section is to be assessed. Reports from work teams should be routed so that progress can be monitored at each administrative level, reaching the Ministry concerned in the form of an Annual Report.

4.2.3 Maintenance costing Estimates of the quantities likely to be involved in the work of road gangs can be costed under three headings:-

- manpower costs including miscellaneous charges
- materials and fuel
- plant and equipment

Unit costs of manpower and plant are frequently used in estimating, to save calculations. These costs are checked annually by comparing them with actual expenses, thus gradually improving the accuracy of costing. Comprehensive lists of operations and their costs should be drawn up to enable more realistic estimates to be made.

4.2.4 Use of results Qualitative studies of road maintenance should be carried out by a special supervisory body with the following roles:

- to assess the quality of maintenance work and the effectiveness of the techniques used,

- to supervise the maintenance programme and to check the accuracy and relevancy of the forecast quantities,

- to decide future action in the road maintenance field,

- to correct possible mistakes.

The results obtained should enable cost comparisons to be made for different maintenance techniques on different kinds of road with different amounts of traffic.

4.2.5 Data processing

4.2.5.1 Purpose Data processing first involves an analysis of quantities achieved. These quantities can be classified by:

- road or road section
- task
- route and traffic density
- plant operating unit and day
- region and country,

on a monthly, quarterly or annual basis.

Study of the results should detect low efficiency poor utilisation of plant and faulty methods.

Secondly a study is made of maintenance costs. These may be assessed as follows:

by road on an overall basis
by road and basic task
by route and traffic density
by basic task on the same route

on a quarterly or annual basis.

Thirdly, if sufficient data exist, each task or gang record can be broken down into costs of labour, fuel, plant and materials etc. Studies of these date over

several years should enable defined maintenance standards to be specified.

The last step is the estimation from the processed data of the annual costs per kilometre. These may be broken down as follows:

by works unit (basic tasks)
by cost component (personnel, materials and equipment)
by type of road (bitumen, earth or track)
by traffic density

This process can be carried out manually through a special department or by computer.

4.2.5.2 Use of data processing Data processing has several functions. First it permits an effective control of the budget, the execution of work programmes, utilisation of manpower and plant, efficiency of methods used and the rational use of resources.

Secondly it makes possible an assessment of the constraints (climatic, geographical and geotechnical) on maintenance costs and also of road deterioration in relation to number and characteristics of vehicles.

The critical analysis of data over several years should permit an improvement in maintenance planning, a gradual transformation of methods and a rational use of manpower and technical resources. Optimum efficiency could thus be achieved while, at the same time, adapting works to the evolving traffic and road network.

4.3 Maintenance of plant and equipment

Road maintenance is very dependent upon the serviceability of plant and equipment. Good works organisation will only be effective if the maintenance of plant and equipment is also well-organised.

4.3.1 Organisation of plant maintenance The responsibility for road maintenance plant and equipment should rest with a special Plant Department independent of the Works Units using the plant. This body would be responsible for all technical and financial control necessary for efficient operation.

The Plant Department would have one or more central workshops with equipment to undertake complete machine and vehicle overhauls, as well as additional regional workshops for smaller repairs. Each would have attached storage facilities and would be in the charge of a 'Fleet Manager'.

Minor maintenance, greasing and inspection of plant would be carried out by mobile workshops or fixed service depots.

Technical management of plant should be performed by a 'Plant Inspection Unit' ensuring constant liaison between the workshops and the sections using the plant. Its chief function would be to keep up-to-date technical data sheets for each machine, listing all inspections and repairs. It would also monitor plant operation and initiate any maintenance work necessary.

4.3.2 Collection and processing of plant data These data can be broken down under the following headings:

- workshop, store, operating and administrative staff,
- power
- fuel and lubricants
- replacement parts
- spare parts
- miscellaneous operating costs
- equipment and materials.

These data would be provided by the Road Maintenance Department and the various sections of the Plant Department. The data would be held centrally in the Plant Department.

This information makes it possible:

- to check fuel and lubricant consumption and plant utilisation, output and operations
- to quantify cost prices of plant, spare parts and operations
- to recommend plant rental and replacement prices, changes in the utilisation of plant and simplification of procedures and training of personnel.

4.4 Personnel training

In many cases poor maintenance is due to human error rather than to deficiencies in plant or equipment. In this respect surveys carried out in African countries have shown the most frequent stumbling block to be the difficulty men have in adapting to the maintenance of roads or machines.

The quality of maintenance works and organisation are highly dependent on human skill and conscientiousness. It is therefore essential that men be educated and trained in ways that will help them to adapt easily to road maintenance work.

4.4.1 Personnel training structure Training should be performed in accordance with the administrative structure of the road maintenance organisation. Both tasks and terminology must be clearly defined to identify objectives and avoid misunderstandings. Professional job descriptions should be established for each skill and for each specific situation (road-site, workshop, mobile team, service depot, stores, etc). Appendix 7 shows a typical administrative structure for Francophone Africa.

Once the general structure of road maintenance skills has been defined, organisation of technical training can proceed.

4.4.2 Organisation of technical training. The first requirement is a survey by quality and number of all men currently employed, identifying qualified staff and those needing different kinds of training. Appendix 8 shows the result of one such survey in Francophone Africa.

The second need is a study of actual personnel requirements at each level, taking into account techniques, equipment available and the extent of mechanisation. This study should be carried out for the base year and then for a target-year allowing for development in roads, traffic and maintenance techniques.

The training officer must then participate in defining the methods and the kinds of training to be offered, having regard both to training needs and to the forms of training currently available.

Furthermore, the arrangement of training schemes should be related to the need fo a sound basis for programming.

This programme should produce a structure for long-term, short-term or on-the-job training aimed at achieving the target-year objectives. Appendices 9 and 10 show flow-charts for the planning of personnel training used in Francophone Africa.

5. MAINTENANCE COSTS

5.1 Components of maintenance cost

The exact cost to the public of road maintenance is difficult to assess since this general heading often covers many other activities of the Public Works Departments.

Budget analysis does not always allow figures for maintenance expenditure to be identified because these amounts may be distributed under several different headings. The principal components of maintenance cost are:

Manpower: executives, contract personnel, assistants, temporary and part-time personnel and possible foreign technical assistance

Plant and equipment: purchases, vehicle maintenance, big repairs, operations, spare parts supplied with new machines

Materials: purchases by the central echelon and by local services from maintenance funds.

All categories of expenditure to be included in maintenance costs should therefore be carefully defined, and accounted as follows:

- Expenditures for each employee should include not only his salary but all related personnel costs borne by the budget, eg social security, leave of absence, medical care, travel and possible other benefits. These expenses must beaccounted for regardless of budget heading.

- All expenses of full-time personnel assigned directly to road maintenance work should count in full.

- Expenses of employees working on organisation, management or part-time maintenance work should only be included according to the time actually spent on road maintenance

- Executives who do not participate directly in maintenance work should be accounted for by fixed amounts and corresponding expenditures designated as overheads.

- Employees working on the operation, upkeep and repair of plant, or in the stores, should be included under Plant and Equipment rather than Manpower.

- Expenditure on materials should include the cost of all materials used including materials taken from central stocks (eg steel beams, metal pipes, bituminous materials). It is desirable that motor fuel and lubricants, being consumables, should be accounted separately.

Plant and equipment expenditures should include

- Direct expenditures: operations, upkeep, spare parts, replacement parts, workshop labour

- Indirect expenditures: provision for renewals, transport costs of incoming and outgoing plant, general costs of overhauls

- Operating, maintenance and depreciation expenditures of central workshops and associated installations and service depots.

5.2 Maintenance costs of unsurfaced roads

5.2.1 Breakdown of costs Cost analyses already carried out in Africa are useful in assessing both the total cost of maintenance work and the distribution of costs under the various heads.

A recent study in the Ivory Coast revealed the following maintenance costs for gravel roads with different amounts of traffic (base year 1970);

ANNUAL COST OF EARTH ROAD MAINTENANCE PER KM

(in CFA Francs)*

Category of road	Fixed costs (1)	Reshaping (2)	Total 1+2 (3)	Resurfacing (4)	Total 3+4 (5)
Jeep-track	9,860	12,550	22,410	-	22,410
Road					
t < 50 veh/day	59,170	33,460	92,630		92,630
50 < t < 100	59,170	50,200	109,370	128,140	237,510
100 < t < 150	59,170	66,930	126,100	149,500	275,600
150 < t < 200	59,170	83,860	143,030	149,500	292,530
t > 200	59,170	100,400	159,570	179,400	338,970

Earth road resurfacing costs corresponding to the figures in column 4 are approximately 900,000 CFA Francs per kilometre

* 1 CFA Franc = 0.02 French Franc ≙ £0.002

A study carried out in 1972 over 1220 km of earth roads in Western Niger gave the following figures for maintenance costs.

Western Niger 1972 - Annual maintenance costs per km for earth roads (20-50 pcu/day)

(Gross, excluding overheads)

	CFA Francs
Spot patching	71,000
Ditches	3,313
Corrugation removal)	19,070
Reshaping)	
Structures	1,920
Traffic signs	1,952
Total	97,255 CFA Francs

This total may be compared with column 3 in the table above.

In Niger regravelling costs in 1972 were about 1,300,000 CFA Francs per km.

Another breakdown showing percentage maintenance costs in Niger for manpower, fuel and materials and plant is as follows:-

Niger 1971-72 - Routine maintenance for complete earth road system
(excluding regravelling)

Region	Manpower	Materials and Motor fuel	Plant (including operating costs)
Western Region	22%	17%	61%
Central Region	13%	21%	66%
Eastern Region	15%	20%	65%
Average	17%	19%	64%

To devise a method for estimating maintenance costs applicable to any country and level of service would require very comprehensive and detailed information on works performed, output of teams and the final result.

For this purpose data collection and processing systems of the kind described in Section 4 are needed. Work of this kind already carried out includes studies in Kenya[B5] and Ghana[B6] while a similar study is in progress in Niger.

5.2.2 Maintenance cost formulae Maintenance costs of unsurfaced roads should include all operations required to maintain the road in its initial state (routine and periodic maintenance). Periodic maintenance costs are often underestimated.

The general formula currently used for earth road maintenance is:

$C = A + Bt$
where C = annual costs per km
A and B are constants
t = average daily traffic

A more detailed formula which better explains the various components of cost is:

$C = A' + B't + f(t)$

where f(t) is the annual cost of regravelling to be carried out every n number of years.

In the Ivory Coast, for instance, maintenance expenditure required to assure average to good driving conditions are assessed as

$C = 75{,}000 + 400t + f(t)$ Francs CFA

(taking f(t) = 0 for average daily traffic under 50 veh/day)

In Niger, in 1972, the formula used in the Niamey Region for maintenance costs was:

$C = 65{,}000 + 350u$ Francs CFA

where u = number of Passenger Car Units per day (PCU).

This formula does not take into account the annual cost of regravelling which in Niger in 1972 was 1,300,000 CFA Francs/km.

If regravelling every 5 years is included, and an average daily traffic of 250 PCU, this formula becomes:

$C = 65,000 + (350 \times 250) + 1/5(1,300,000) = 412,500$ Francs CFA per km per year.

Similar formulae were obtained for Guinea[F14] during a study conducted in 1967. The following figures represent formulae for earth road maintenance costs in the three main geographic and climatic zones of Guinea. Costs are expressed in Guinean Francs for 1967, on the basis of n numbers of vehicles per day, all categories combined. Fixed costs of management or supervisory personnel are not included but expenditures on regravelling are included (in km/year):

- Coastal and Central Guinea	$C = 80,000 + 2,100\ n$
- Upper Guinea	$C = 69,000 + 2,100\ n$
- Forest areas in Guinea	$C = 80,000 + 2,300\ n$

In these formulae, the part of the cost attributable to regravelling is 1100 n, except in Tropical Guinea where it is 1300 n.

A formula often quoted for East and Central Africa, which includes regravelling cost, is:

$$C = £(50 + 2Q) \text{ per km per year}$$

where Q is the average daily traffic.

This is indicative of the order of costs only and is not based on any detailed or recent study.

Studies carried out by the Crown Agents in 1971 in three separate geographic zones in Ghana[B6] yielded the following formulae for annual maintenance costs per mile given in N¢ (n = number of vehicles per day):

(1N¢ = £0.33 3.3 French Francs = 167 CFA Francs)

	Northern zone	Middle and Western zone	Southern and Eastern zone
Gravel roads			
Routine - grass, culverts, etc	470	508	508
Recurrent - potholes, grading etc	30 + 1.22n	50 + 1.32n	30 + 1.22n
Periodic - regravelling	538 + 1.65n	538 + 1.65n	538 + 1.65n
Totals	1038 + 2.87n	1096 + 2.97n	1076 + 2.87n
Bituminous roads			
Routine - grass, culverts etc	428	462	462
Recurrent - potholes cracks etc	7 + 1.03n	7 + 1.03n	7 + 1.03n
Periodic - surface dressing, regravelling shoulders etc	731 + 0.25n	731 + 0.25n	731 + 0.25n
Totals	1166 + 1.28n	1200 + 1.28n	1200 + 1.28n

Independent studies carried out by a firm of consulting engineers, also in 1971, gave results which agreed fairly closely in respect of bituminous roads[67, B8]. For gravel roads, however, there was a considerable difference for the higher traffic volumes as compared with the Crown Agents' figures, reflecting the difficulty of estimating accurately future regravelling needs. The figures were:

Gravel roads Cost per mile per year NC/561 + 9.1n

Bituminous roads

Class 1c 1410 + 2.7n (low standards of construction)
Class 1b 1410 + 2.2n (medium standards)
Class 1a 1410 + 1.7n (high standards)

For bituminous roads, formulae involving average daily traffic can only be used rationally where the traffic mix is similar, because of the very different damaging effect of different wheel-loads. An approach towards a formula using numbers of standard axles[B2] can be made with unpublished data from Malawi. Thus, in the region concerned, 200 commercial vehicles per day were found by wheel load surveys to be equivalent to 100 standard axles. Also, it was estimated that 2 per cent of the carriageway needed to be repaired each year. Then, using local prices and assuming the repaired area to be divided equally between surface patching and deeper repair work, we have:

Fixed costs (£ per km/year)

	Grass cutting, culverts etc	30
	Surface dressing (every 7 years)	150
	Overheads	11
		191
Variable costs	Surface patching (1 per cent carriageway area)	25
	Deeper repair work (1 per cent carriageway area)	63
		88

Then total costs per km per year:
$C = (191 + 0.88S)$

where S is the number of standard axles/day.

6. RECOMMENDATIONS AND CONCLUSIONS

To improve the quality of road maintenance and to further the aims of research into better organisation and methods, recommendations can be made under four main headings:

- techniques and materials
- information and data processing
- training
- standards

6.1 Techniques and materials

6.1.1 Road test sections Test sections should be established on roads of different kinds to enable the effect of traffic on road behaviour to be studied. Data to be recorded should include construction details, properties of materials and condition

of the road at the beginning of the study, and all environmental factors involved in the subsequent deterioration of the road (eg rainfall, humidity, quality of materials used in its maintenance, etc). As much traffic data as possible must also be collected including quantity, type, season and, in the case of bituminous roads, axle loads and deflection measurements as well.

Comparison of data of this sort over a given period of time should yield the following useful information:

for unsurfaced roads

- the quality of the work carried out,
- the frequency of reprofiling operations in relation to traffic,
- the deterioration of the carriageway in relation to traffic and maintenance methods,
- the behaviour of the road under seasonal traffic,
- the minimum thickness of resurfacing required,
- the rate of wear and resistance to corrugations in relation to the quality of materials;

for bituminous roads

- the effect of traffic volume and axle-loads on maintenance requirements,
- the assessment of maintenance requirements on the basis of deflection measurements:

for both kinds of road

- the relation between construction standard and future maintenance requirements.

Test sections should be established in many different countries and the necessary systems of data collection and processing set up.

6.1.2 Resources of road materials It commonly happens that, with the passage of time, highway studies are forgotten and their data totally disregarded. Borrow-pits opened for the construction of a road may be completely ignored during maintenance operations, because of lack of information in Works HQs or because the information does not come readily to hand.

It is strongly recommended that borrow-pit maps be maintained by central or regional works offices, which would make borrow-pit location a simple matter. Data sheets should be kept describing the chief characteristics of the material and could be updated by specific laboratory test programmes. This work should be done by a special unit.

The use of data of this sort would mean savings in the cost of soil investigations as well as rapid knowledge of borrow-pit resources in a given area. With a better knowledge of the physical characteristics of the materials available, their performance in the road could be more usefully compared.

6.2 Information and data processing

Road maintenance services should develop data collection systems able to provide quick and detailed information on works carried out and in hand. These should emphasise the numerical data most closely concerned with planning and supervision of road maintenance.

Data processing of this sort is time-consuming and is therefore seldom used in general practice. There is a need for special offices at Central level to do the work of data processing and monitoring progress.

6.3 Training

Those responsible for road maintenance services should take a closer interest in the training requirements of their personnel. This training must be closely associated with both organisation and works.

6.4 Maintenance standards

There is an urgent need for objective standards of road maintenance, concerning in particular:

defin ed maintenance standards
simple systems for assessing road condition
realistic work-output values.

Highway authorities and Governments should co-operate to the full, between themselves and other road agencies, in developing these standards. Full use should be made of new equipment becoming available for assessing road condition, if necessary sharing the costs of more expensive items between the organisations concerned.

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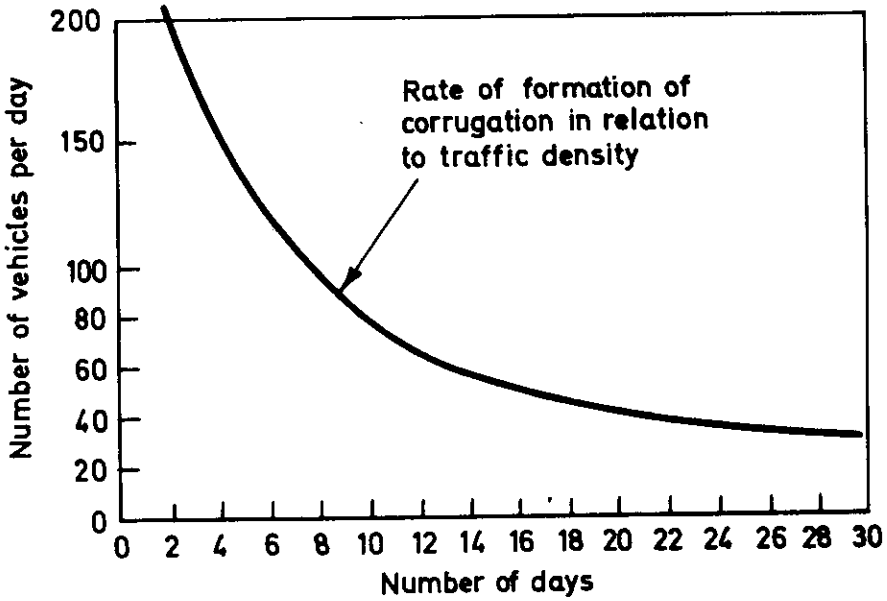


Ref. : Kaolack road - Senegal

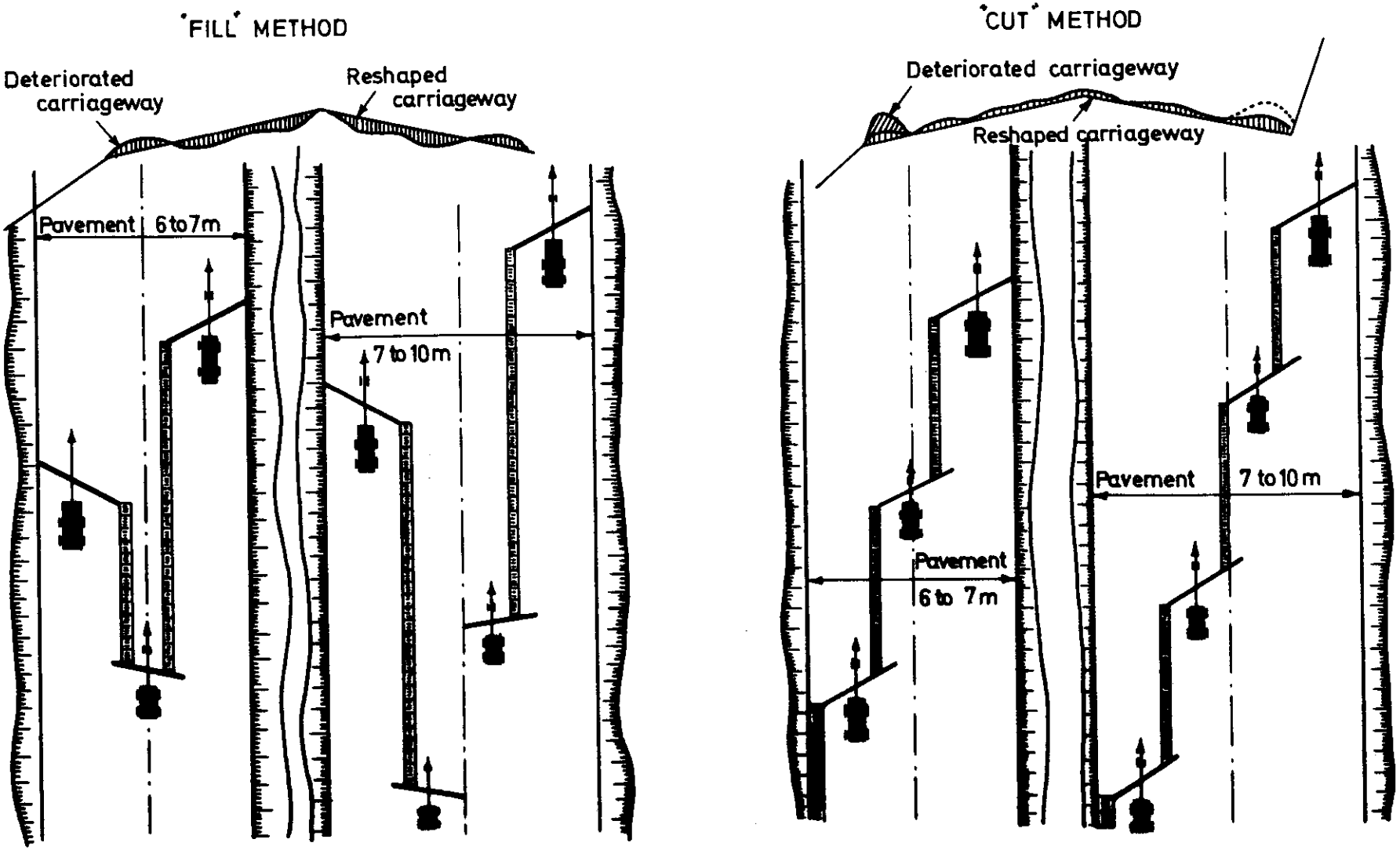
Source : Earth roads - by M.G. Mellier

FREQUENCY OF BRUSH TRACTOR RUNS
FOR CORRUGATION REMOVAL - NIGER

Veh / day	Daily frequency	Road distance maintained by brush use
120	1 run per day	30 km
100	1 run per 1·5 days	45 km
80	1 run per 2 days	60 km
50	1 run per 4 days	120 km
30	1 run per week	180 km

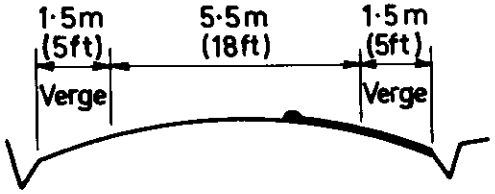
Note : One daily run for 120 veh./day represents a more frequent operation than one weekly run per 30 vehicles (i.e. one run for every 210 vehicles). This is because for 120veh./day efforts are made to obtain a higher service level

Appendix 1
RATE OF FORMATION OF CORRUGATION IN RELATION TO TRAFFIC DENSITY



Appendix 2A
CROSS RESHAPING OF CARRIAGEWAY

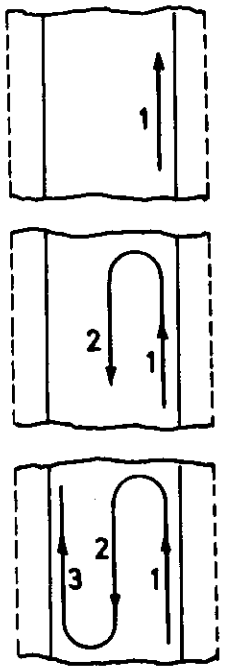
SEQUENCE OF OPERATIONS FOR MAINTAINING EARTH ROADS WITH A BLADE GRADER AS USED IN ZAMBIA



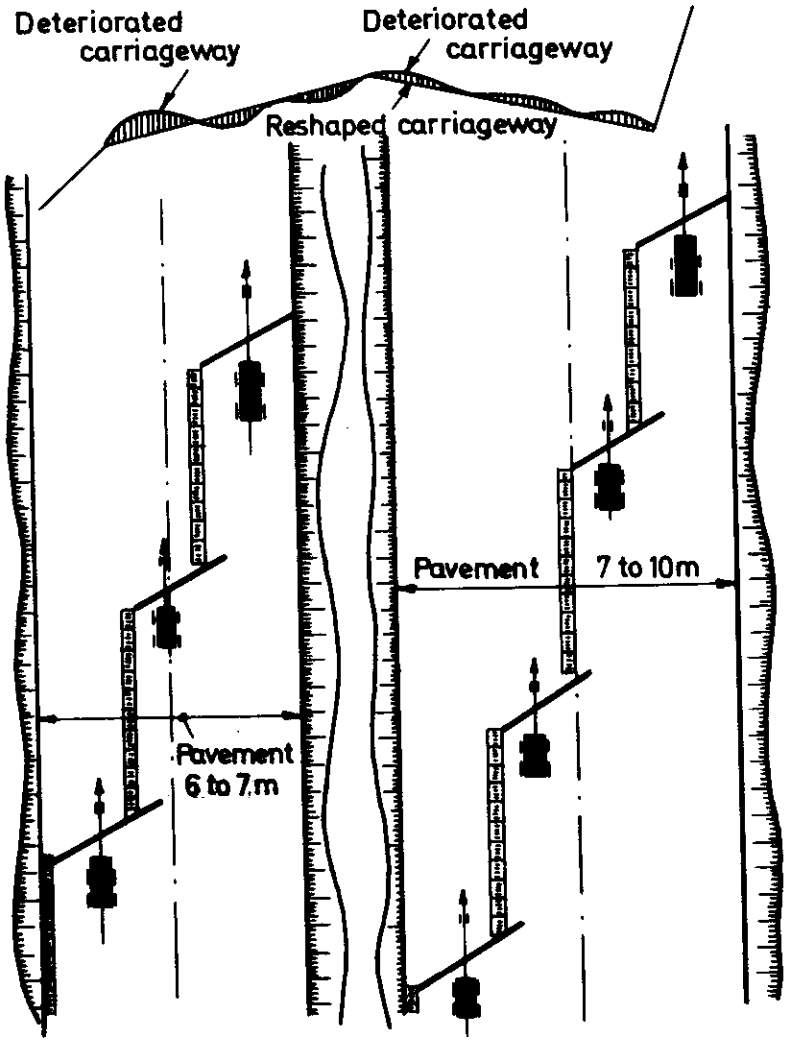
1st pass of grader, windrow formed 1·5 m (5ft) from edge of road

2nd pass of grader, first windrow spread, second (smaller) windrow formed

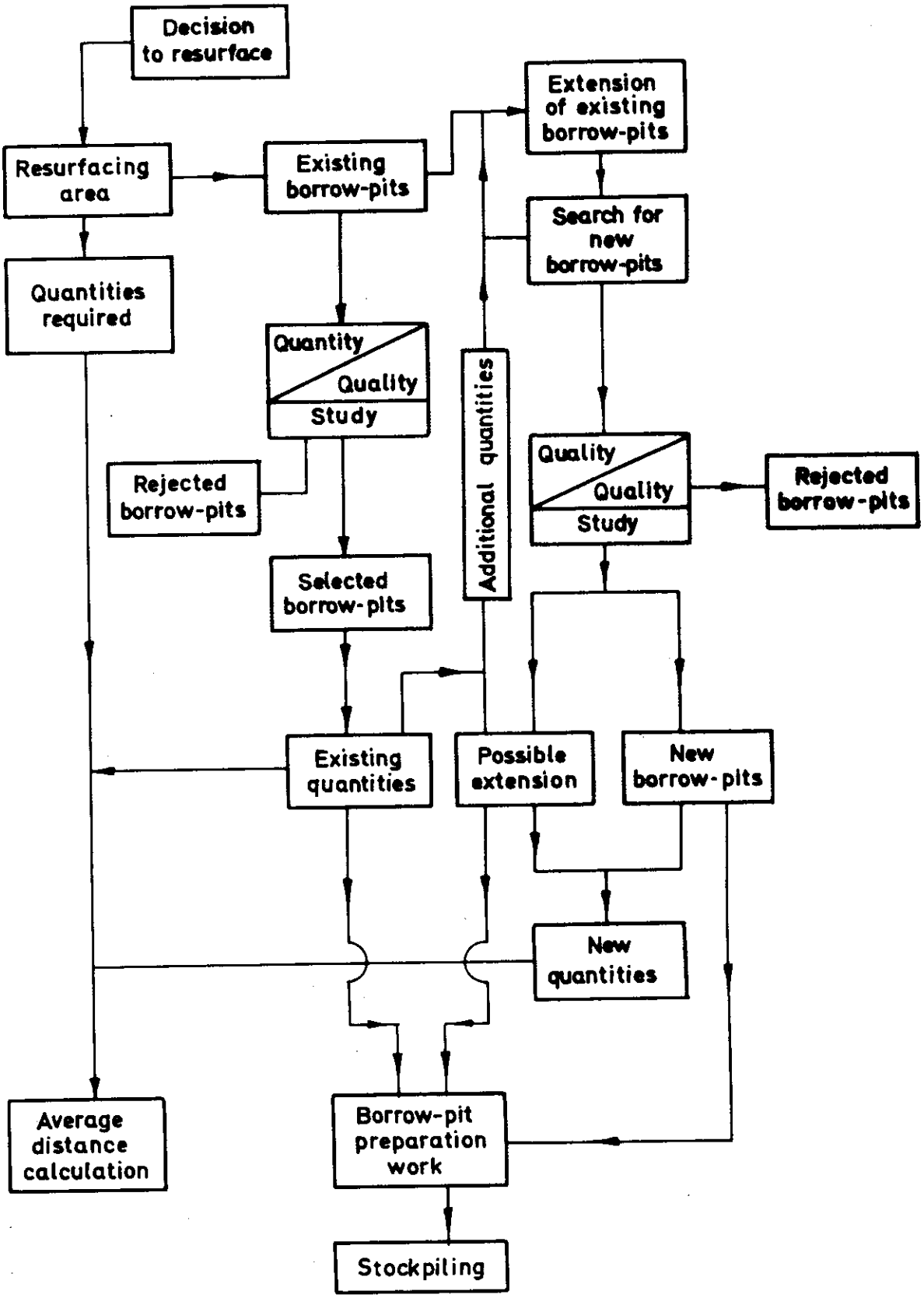
3rd pass of grader, second windrow spread as far as opposite verge



"MIXED PROFILE" METHOD



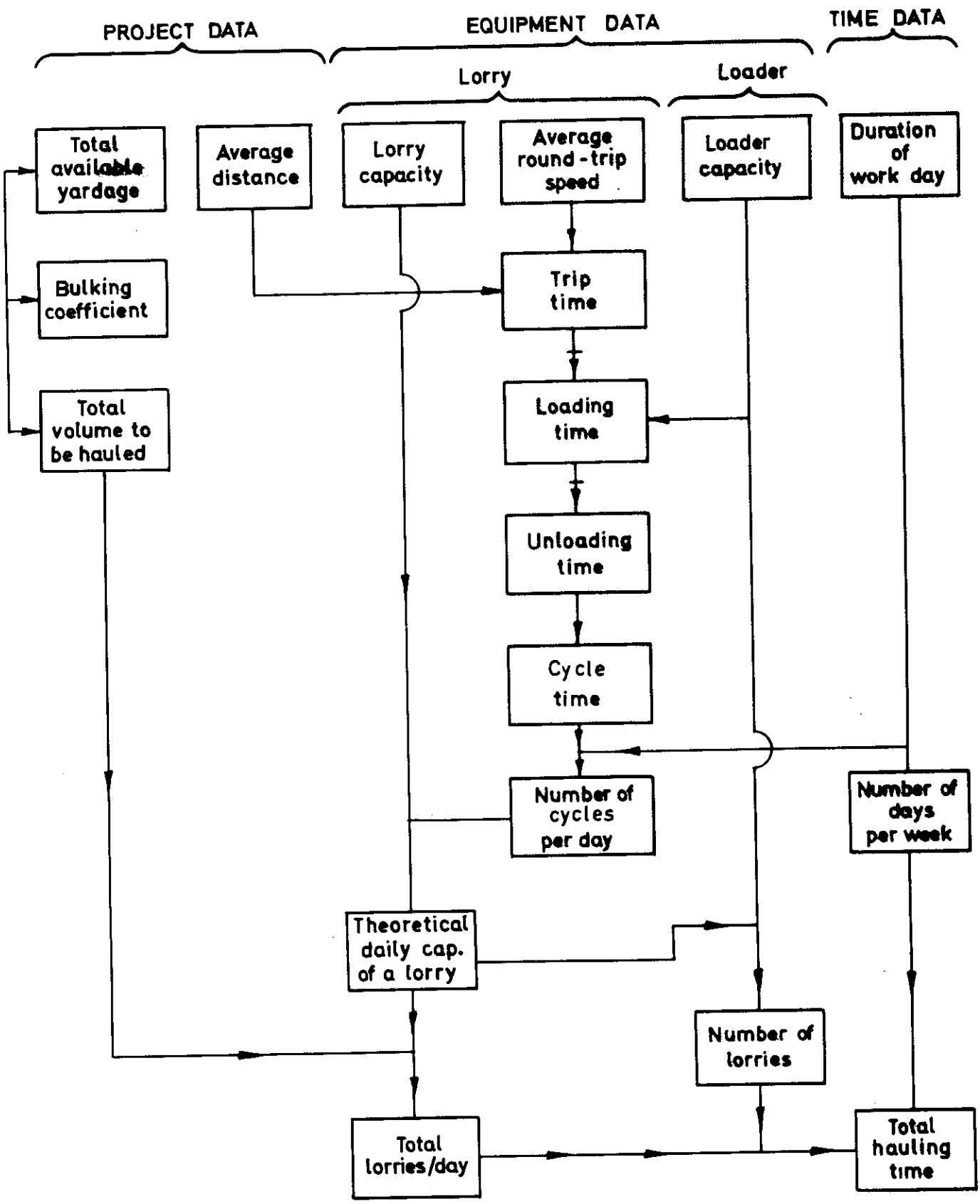
Appendix 2B
CROSS RESHAPING OF THE CARRIAGEWAY



Appendix 3A

RESURFACING PLANNING FLOW CHART

ORGANISATION PLANNING
(LOADING AND HAULAGE)



Appendix 3B
RESURFACING PLANNING FLOW CHART

APPENDIX 4

METHOD FOR REPAIRING POTHOLES WITH BITUMINOUS PREMIX USING A CENTRAL MIXING PLANT(B7)

Equipment

1 Hot asphalt mixer
1 batching box (approximately 0.03m3)
7 shovels
1 5 or 7 tonne long wheel base truck
1 hand spraying unit for bituminous emulsion
250 kg vibrating roller
2 picks
1 broom
1 rake
1 set traffic control equipment

Personnel

Mixing Gang

1 supervisor
1 mixer operator
2 batchers
2 banksmen

Spreading Gang

1 supervisor
2 spreaders
2 banksmen
1 driver
2 traffic controllers

Standard Mix

The standard mix is 1.5 parts of stone dust (passing 3.35mm) to 1 part of 12.7mm chippings, with 6% by weight of RC2 bitumen. When using 0.03m^3 batching boxes, this mix becomes 0.045m^3 of stone dust to 0.03m^3 of 12.7mm chippings to 6.8l of bitumen.

Method

The materials are mixed centrally at the depot where the mixer permanently stands. The bitumen temperature should be between 60°C (140°F) and 100°C (212°F). The batching and mixing takes place continuously until the forecast requirement is produced and stockpiled.

The spreading gang travels to the depot to load up the flat truck with premix. Usually this is done first thing in the morning and enough premix is taken for the day's work.

The emulsion distributor, vibrating roller, emulsion drums, dust and men are taken to site on the flat truck.

The areas to be patched are marked out and prepared, by the four labourers on the spreading team, picking away a 150mm surround of sound material to form a vertical face, then sweeping away the debris and dressing the exposed surface with emulsion.

The two banksmen then board the truck and break up and throw down the premix on to the prepared area. The two spreaders break down the premix further whilst spreading it to the required surface shape, leaving it slightly proud of the adjacent surface.

When the area is fully covered, the surface is dressed with emulsion and the blinding dust thrown down and spread. The blinded area is then rolled.

Standards

The standards have been produced in terms of distance between the depot and the site. An allowance of one hour per day has been made for loading of premix.

DISTANCE BETWEEN SITE AND DEPOT km (miles)	RATE OF WORKING sq m/gang day (sq ft/gang day)
8 (5)	130 (1375)
16 (10)	120 (1250)
24 (15)	100 (1125)
32 (20)	90 (1000)
40 (25)	80 (875)
48 (30)	70 (750)

Rates of working for light patching with premix for various distances

APPENDIX 5

METHOD FOR REPAIRING POTHOLES WITH MATERIALS CONTAINING BITUMEN EMULSION MIXED ON SITE (B7)

Equipment

1 5 tonne long wheel base truck
1 mixer (approximately 0.07m^3)
1 batching box (approximately 0.03m^3)
1 spraying unit for bituminous emulsion
1 250Kg vibrating roller
1 tipper (part-time)
1 pick
4 shovels
2 brooms
2 rakes
1 set traffic control equipment

Minimum Personnel

1 supervisor
1 mixer operator
1 batcher
3 spreaders
2 labourers
2 drivers
2 traffic controllers

Standard Mix

The standard mix is 1.5 parts of stone dust (passing 3.35mm) to 1 part 12.7mm chippings with 12% by weight of emulsion. When using 0.03m^3 batching boxes, this mix becomes 0.45m^3 of stone dust to 0.03m^3 of 12.7mm stone to 3.4l of emulsion.

Method

The flat truck is permanently equipped with mountings for three drums of emulsion behind the cab, the mixer mounted to discharge at the tail, and with three partitioned compartments to receive stone chippings and dust.

The roller, emulsion sprayer and men are transported to and from the site by the tipper which is free for other duties during the working day.

The stone and dust have been prev iously dumped at strategic points along the road using the tipper.

The area to be repaired may be either an area of central carriageway or a length of edging. The repairing technique is the same for both.

The area to be patched is marked out by the supervisor. This area should include both the failed zone and a 150mm wide strip of sound surfacing surrounding the zone, as in Appendix 4.

The area is then prepared by the two labourers as before.

After preparing the first area, the two labourers move ahead to prepare the next area(s) so that there is always work available for the mixing and spreading operation and there is no hold up whilst preparation takes place. As a guide, there should be an area equivalent to one hour of mixing and spreading work prepared ahead of this operation.

As preparation of the first area is complete, the flat truck draws up so that the mixer can discharge directly on to the first area.

The first load, which has been batched and mixed during preparation work, is discharged on to the area and spreading commences. The spreaders spread the mix over the area to the correct surface shape leaving the surface slightly proud of the adjacent carriageway. Batching, mixing, discharging and spreading are carried on continuously until the first area is covered.

During this time the two labourers will have finished the preparation of the areas to be patched in the next hour and are free to assist with batching of materials, dusting and rolling.

After spreading of the first patch, the dust for the blinding is thrown down and the lorry moves on to the second area, One of the labourers remains at the first patch spreading the dust and then rolling the patch with at least six passes of the vibrating roller.

The operation continues in this manner with two men permanently batching and mixing, three men permanently spreading, and two men partly preparing, batching, blinding and rolling.

As originally stated, this is a minimum gang size for effective operation, The best gang size is achieved by adding a minimum of four men and preferably five men, and to operate with two spreading teams.

The five men are disposed as three spreaders, one batcher, and one labourer on the mixed duties.

Work proceeds in exactly the same manner as described above except that there are two spreading teams of three men each, and batching and mixing becomes a full time operation with three men permanently involved, often supplemented by one of the labourers.

Standards

The output for isolated patches is different from the output for edging repair. The standard rates of working for both these jobs and for the minimum and optimum temas are as follows:

	PATCHING	EDGE REPAIR
Minimum Team	180 sq m/gang day (1900 sq ft/gang day)	200 sq m/gang day (2200 sq ft/gang day)
Optimum Team	280 sq m/gang day (3000 sq ft/gang day)	280 sq m/gang day (3000 sq ft/gang day)

Rates of working for light patching using minimum and optimum teams. Mixing on site.

APPENDIX 6

LIST OF EARTH ROAD MAINTENANCE TASKS

TASK NO	TASKS	TASKS WORK BREAKDOWN
I	Carriageway hand patching Basic unit : linear metre of road assigned to sector	. Filling of potholes (m^3) . Occasional carriageway renewal (work unit : m^3) . Rock removal on carriageway (m^3) . Laterite extraction at borrow-pit (m^3) . Borrow-pit preparation (in m^3 for stripping and m2 for brush clearing) . Laterite transport and spreading (m^3 and km) . Sand removal on road
II	Reshaping Basic unit : linear metre of road assigned to sector	. Reshaping of carriageway with grader (km of road) . Scraping of corrugations with grader blade (km of road) . Scraping of powdery corrugations with tractor-drawn blade (number of runs/day)
III	Ditch drainage Basic unit : linear metre of road assigned to sector	. Cleaning of side ditches . Cleaning or creation of divergent ditches . Creation of intercepting ditches . Protection of ditch edges by metalling or pitching (m^3 of metalling) . Fascine-work or gabion-work
IV	Maintenance of drainage structures and bridges Basic unit : Number	. Brush clearing of stream and river beds and of downstream outfalls (m^2) . Brush clearance in immediate vicinity of structures (m^2) . Cleaning of structures (number of structures) . Reconstruction of structures (quantities of materials) . Repair of structures (quantities of materials) . Widening of box-culverts or barrels (no of widenings) . Construction of new small structures (units and diameters) . Renewal of pitching on riprap of access embankments (m^2 or m^3) . Inspection of sound condition of piers and abutment (units) . Extraction, transport and laying of rocks near structures (m^3) . Inspection, repair and maintenanc of concrete or steel bridges (Kg of paint, cubic metre of concrete or mortar, depending on work done). . Protection against underwashing of piers and abutments (m^3)

V	Maintenance in vicinity of road (other than ditches) Unit : m2 per km/basic road	• Brush clearing and cutting of roadbed edges (m^2) • Brush clearance of slopes, fills and cuts (m^2) • Brush clearance of visibility areas on curves • Maintenance of slopes, repair of eroded sections and slides (m^3 of materials) • Repair of collapsed or eroded banks (m^3 of materials) • Protection of banks or cuts • Removal of dunes in vicinity of road • Plantings in areas subject to water erosion • Removal of termitaries on edge of roadway
VI	Traffic signposts Basic Unit : linear metre of road assigned to sector	• Installation of direction signposts at crossroads (number of units) • Installation of village or town name signposts (number) • Installation of triangular danger signposts for roads and bridges (number) • Manufacture and installation of milestones and distance signposts (number) • Purchasing of all signposts, materials, paint and various materials for traffic signs
VII	Improvement maintenance (specific and non-continuous operations - amortisation overal several years) Basic unit : linear metre of improved road	• Straightening of curves • Adjustment of vertical alignment • Widening of carriageway • Alignment adjustments • Improvement of critical points (bridge accesses, town or village entrances, etc...)
VIII	Resurfacing of carriageway Basic unit : km of resurfaced road; amortisation over several years	• Location, stripping and clearing of borrow pits • Preparation and shaping of carriageway • Stocking of carriageway materials • Loading of materials • Transport and unloading of materials • Spreading of materials with grader • Arrangement, installation and operation of water points • Water transport and sprinkling • Compaction of carriageway and occasional in-place-mixing • Shaping of carriageway surface • Improvements to road accesses

APPENDIX 7

OUTLINE OF A HIGHWAY MAINTENANCE SERVICE
IN FRANCOPHONE AFRICA

ADMINISTRATIVE LEVEL	MANUAL MAINTENANCE	MECHANISED MAINTENANCE	EQUIPMENT MAINTENANCE
9	P.W. District Chief		Equipment Division Chief → Equip. Head; Equip. Ass't. Head; Equip. District Mechanical Tools Service
8	P.W. Subdivision Chief		Technical Service Head Equipment Inspector Technical/Mechanic
7	P.W. Technician		Workshop Head → - Machine tools - Machines - Vehicles-Lorries - Forge, Etc..
6	P.W. Supervisor		Workshop Foreman/Mechanic Mechanic/Repairman
5	Area Supervisor	Equip. unit superv.	Warehouse Supervisor
4	Team Supervisor	Team Supervisor	Warehouse Team Supervisor → Workshop specialist; Mechanic/Repairman
3	Skilled Roadman Woodcutter Mason Structure Special.	Equip, Operator Lorry Driver	Warehouse Assistant Routine maintenance mechanic (Service Station)
2	Ass't Mason Records Man Surveyor	Assistant	Assistant → - Mechanic - Warehouseman
1	Labourer	Labourer	Labourer

Appendix 8 - General summary of existing personnel and future needs

SUMMARY OF EXISTING SUPPLY AND DEMAND

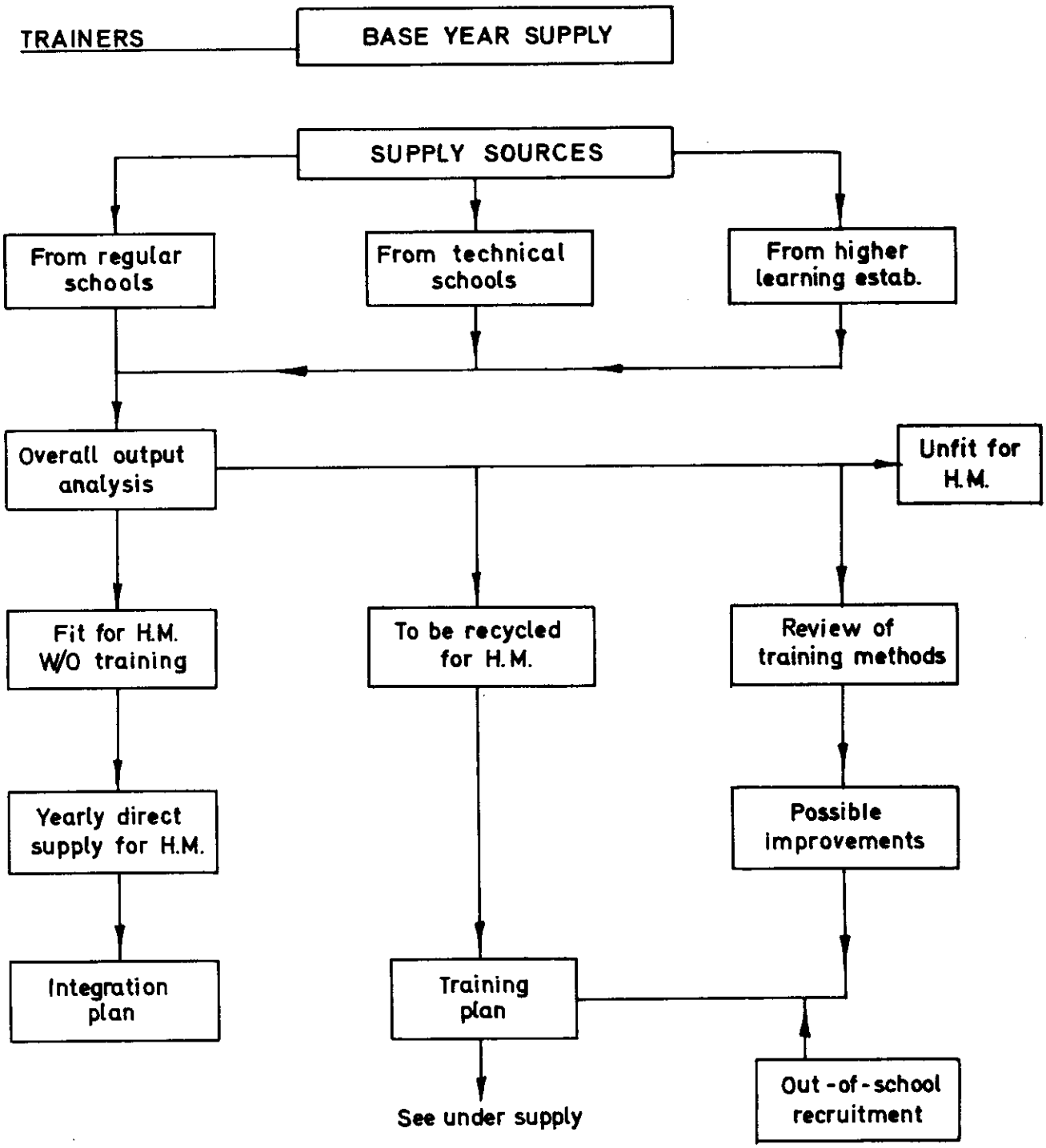
	1974 Needs	Existing Personnel				Difference	To be recruited	Literacy trng. req. (exist. pers.)
		Fit for duty	Short training	Extensive training	Total			
	1	2	3	4	5 (2+3+4)			
Sector supervisor	66	25	12	8	45	-21	21	5
Team supervisor	184	60	35	15	110	-74	74	20
Road unit supervisor	31	15	3	7	25	-6	6	-
Mobile mechanic/repairman	24	3	-	9	12	-12	12	-
Workshop mechanic/repairman	75	10	5	15	30	-45	31(2)	20
Skilled worker	100	90	15	15	120	+20	-	-
Routine maintenance mechanic	12	-	6	-	6	-6	6(1)	-
Plant operator	118	100	18	-	118	-	-	5
Lorry driver	396	200	110	-	310	-86	86	10
Total	1006	503	204	69	776	-250 +20	236	60
Training			204	69			236	60

Notes (1) 6 from skilled workers.

(2) 14 from skilled workers.

PERSONNEL SUPPLY TABLE

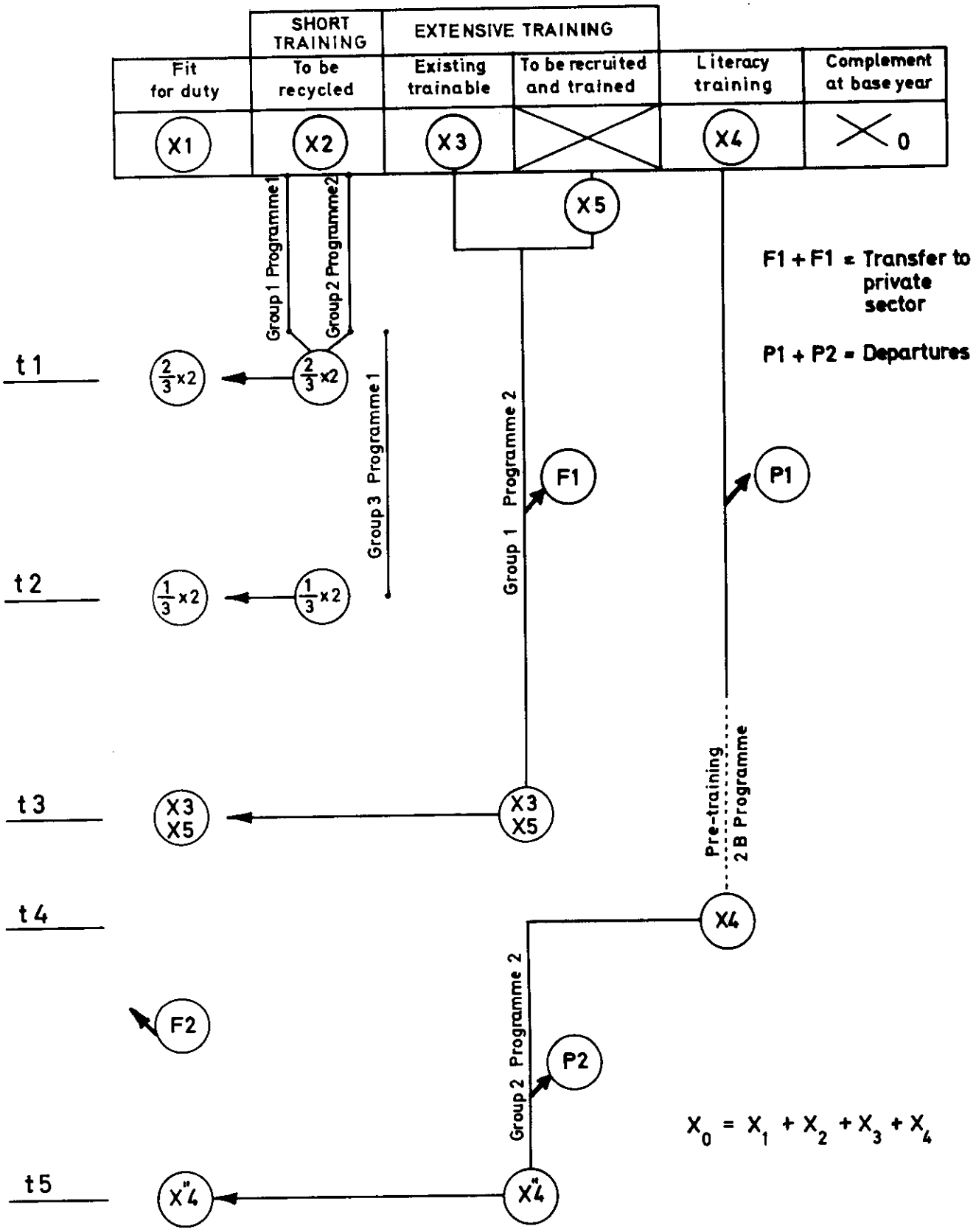
HIGHWAY MAINTENANCE (H.M.)



Appendix 9

TRAINING SUPPLY PLANNING FLOW CHART

TRAINING OF .....



$X_0 = X_1 + X_2 + X_3 + X_4$

Appendix 10
OPERATIONS FLOW CHART

Plate 1 CRACKING OF AN UNSTABILISED BITUMEN SURFACED ROAD ON AN EMBANKMENT IN CENTRAL AFRICA

Plate 2 "BLOCK-CRACKING" OF A CEMENT-STABILISED ROAD IN SOUTHERN AFRICA

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