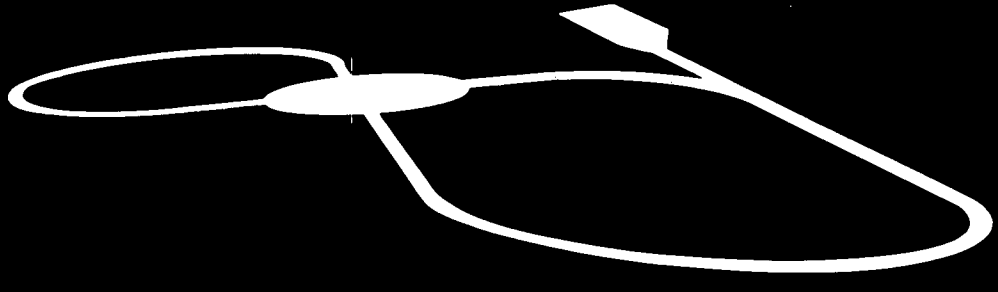
TRRL Research Report 145

Transport and Road Research Laboratory



Department of Transport

A view of road maintenance economics, policy and management in developing countries

by R Robinson

A VIEW OF ROAD MAINTENANCE ECONOMICS, POLICY AND MANAGEMENT IN DEVELOPING COUNTRIES

ABSTRACT

Work that has been carried out at TRRL in the field of road maintenance in developing countries is reviewed under the headings of economics and policy, project implementation, and management. The Report, together with the second editions of Overseas Road Notes 1 and 2, provides a compendium of the current state-of-the-art in this field as viewed from TRRL.

Numerical examples are given to illustrate the economic benefits of road maintenance and some of the reasons for the poor conditions of road networks in developing countries are discussed. Different approaches to carrying out maintenance are described, including a discussion of equipment and labour-based methods, and of using contractors. Recommendations are made on priorities for budgeting.

The background to the increase in numbers of road maintenance projects is given and the two main types of these projects are described. Results of a TRRL study into maintenance management projects are given including recommendations for their future implementation. Methods of assessing existing maintenance capability are described.

Maintenance management systems are described in terms of their objectives and their component steps, and the recommendation is made that maintenance frequencies should be determined on an economic basis using whole-life costs. Examples of the use of such methodology to the management of unpaved roads are given. The need for condition measurement surveys to determine maintenance needs for paved roads is described and different methods of rapid assessment are discussed. Comments on paved road intervention levels are also given.

The final part of the Report looks at the possible future for road maintenance in developing countries and discusses the way ahead under the headings of network priorities, finance and the need to improve efficiency.

1 INTRODUCTION

1.1 BACKGROUND

Work on road maintenance in developing countries has been carried out at TRRL since 1978. The impetus for this was the result of research carried out by TRRL in conjunction with the World Bank in the 1970s (Abaynayaka *et al.* 1977) which demonstrated for the first time, in a quantitative way, the key importance that road maintenance had on vehicle operating costs. This, in turn, highlighted the dramatic effect that spending, or failing to spend, relatively small amounts of money on road maintenance could have on the economic return of a road construction project. At the same time, several donors were becoming increasingly alarmed about the poor condition of road networks in many developing countries and that the level of deterioration was increasing.

Early work in this field at TRRL concentrated on developing simple and easy-to-use guides for engineers aimed at managing and carrying out road maintenance. These were produced in conjunction with Scott Wilson Kirkpatrick & Partners and were published in 1981 as Overseas Road Notes 1 and 2. French and Spanish versions followed. Both have subsequently been revised following further development work and second editions have now been issued (TRRL Overseas Unit 1987, 1985). In addition, TRRL collaborated with representatives of the French and German governments to produce the ECA Road Maintenance Handbook (United Nations Economic Commission for Africa 1982), 20 000 copies of which were printed for free distribution within Africa. This book was aimed at road maintenance foremen and was published in both English and French.

TRRL have carried out studies of road maintenance in four main areas:

(i) economics and policy issues
(ii) maintenance project implementation
(iii) management issues
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Results of these studies have been reported in various conference proceedings, journal articles and TRRL publications. The purpose of this Report is to draw all of this information together so that this document, together with the second editions of Overseas Road Notes 1 and 2, provides a compendium of the current state-of-the-art on road maintenance in developing countries as viewed from TRRL.

Section 2 of this Report deals with maintenance economics and policy issues, whilst Section 3 discusses difficulties that have arisen in maintenance project implementation, together with some proposals for assessing the capability for carrying out maintenance in individual countries. Section 4 covers those aspects of management that are beyond the scope of Overseas Road Note 1. Maintenance operations are not covered in this Report since the recommendations resulting from TRRL research are the subject of Overseas Road Note 2. The background research to ORN2 is included in various TRRL Reports (Hitch 1981, Roberts 1982, 1983, Roberts and Gaituah 1983, Jones 1984a, b, c, Jones and Robinson 1986).

1.2 DEFINITION OF MAINTENANCE TERMS

The purpose of maintenance is to ensure that the road does not fail before the end of its design life. In doing this, maintenance reduces the rate of road deterioration, it lowers the cost of operating vehicles on the road by providing a smooth running surface, and it keeps the road open on a continuous basis by preventing it from becoming impassable. It is a relatively low cost activity and specifically excludes those works designed to increase the strength or improve the alignment of the road.

Upgrading aims at providing additional capacity when a road is nearing the end of its design life or because there has been an unforeseen change in use of the road. Typical examples of upgrading projects are the paving of gravel roads, the provision of strengthening overlays for paved roads and the widening of roads.

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Rehabilitation is needed if the road has deteriorated beyond the condition at which overlaying is a satisfactory engineering alternative. This may often be because the road has received insufficient maintenance to enable it to provide an appropriate level of service to the end of its design life. Additionally, rehabilitation may be needed because the original road was not built to the standards of quality required by the original design. Reconstruction to provide a new alignment should be considered as an upgrading project as described above.

2 ECONOMICS AND POLICY ISSUES

2.1 THE ECONOMIC JUSTIFICATION OF MAINTENANCE EXPENDITURE

2.1.1 Reducing road deterioration

Even with adequate maintenance, roads will deteriorate over time. The rate of deterioration will depend on a number of factors including traffic loading, road strength and climate. Eventually the end of the design life is reached and there is a need for strengthening or reconstruction. As shown in Table 1, these are very expensive activities and should therefore be postponed for as long as possible by carrying out effective and timely maintenance.

TABLE 1

Costs in US dollars per km

	Paved	Unpaved
Routine and recurrent maintenance	500	1 000
Periodic reseal (after 5 years)	12 000	
Overlay (after 10 years)	42 000	
Regravelling (after 5 years)		8 000
Reconstruction	175 000	45 000
Annual maintenance cost (undiscounted apportioned over 10 years)	6 000	2 500
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(Source: Faiz and Harral 1987)

Digest of Research Report 145

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1988

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ECONOMICS AND POLICY ISSUES

The economic benefits of road maintenance are illustrated by examples showing the escalation in deferred maintenance costs if work is not carried out in a timely manner. Further examples show the effect of poor maintenance on vehicle operating costs and the long-term consequences of diverting the maintenance budget to extend the length of the road network when resources are limited.

The results of condition surveys of networks in developing countries are given which show that only 30 per cent of paved primary roads are in good condition compared with 85 per cent in the UK. There is a worldwide rehabilitation backlog of $41 billion and the limited evidence that exists suggests that the situation is deteriorating. Reasons for the poor condition of roads are discussed under the headings of network and traffic, funding, efficiency, and the consequences of the world economic recession of the early 1980s. The role that donors continue to play in the road maintenance field is also discussed.

Different approaches to carrying out maintenance are described, including a discussion of equipment and labour-based methods. The scope for using contractors to avoid the monopoly position of the maintenance organisation is discussed against the background of trying to increase efficiency. The need is stressed for appropriate design and control of construction, and the problem of maintenance funding is addressed. Recommendations are made for priorities for budgeting.

MAINTENANCE PROJECT IMPLEMENTATION

The background is given to the increase in numbers of maintenance projects in recent years. These projects comprise two types: institution building projects and those designed to overcome a particular short-term problem. The time horizon for institution building projects needs to be long, since it is unrealistic to expect to make fundamental changes to the workings of an organisation which are sustainable in less than about 10 years. Short-term projects will only be appropriate in a very few cases.

Results of a TRRL study into maintenance management projects are given including recommendations for their future implementation. Methods of assessing existing maintenance capability are described, including the use of measurements of equipment availability, periodic maintenance frequencies and road condition. The effect of poor future road maintenance on the viability of new construction projects is discussed, and recommendations are made about the need to take this into account when carrying out project appraisals.

MANAGEMENT ISSUES

Pavement management systems are described in terms of their objectives and their component steps, and the recommendation is made that maintenance frequencies should be determined on an economic basis using whole-life costs. Examples of the use of such methodology in the management of unpaved roads are given and optimum grading frequencies are derived for different conditions. A method of assessing regravelling requirements is also outlined. The need for condition measurement surveys to determine maintenance needs for paved roads is described and different methods of rapid assessment are discussed. Comments on paved intervention levels are also given.

* * *

The final part of the Report looks at the possible future for road maintenance in developing countries and discusses the way ahead under the headings of network priorities, finance and the need to improve efficiency.

The work described in this Digest forms part of the programme carried out by the Overseas Unit (Unit Head: Mr J S Yerrell) of TRRL for the Overseas Development Administration, but the views expressed are not necessarily those of the Administration.

If this information is insufficient for your needs a copy of the full Research Report RR145, may be obtained, free of charge, (pre-paid by the Overseas Development Administration) on written request to the Technical Information and Library Services, Transport and Road Research Laboratory, Old Wokingham Road, Crowthorne, Berkshire, United Kingdom.

If the required routine and recurrent maintenance are not carried out, drainage will be ineffective and surface defects worsen, both of which will result in water penetrating the structure of the road. For paved roads, the resulting road distress will require that periodic maintenance is needed prematurely which is at least twenty times more costly than routine and recurrent maintenance. Failure to carry out periodic maintenance at the appropriate time soon leads to the need to carry out road strengthening which is at least three times more costly than periodic maintenance. If this strengthening is not carried out soon enough, major deterioration sets in and rehabilitation will be required which is up to fifteen times more costly than periodic maintenance. Clearly, there is considerable economic benefit in carrying out appropriate maintenance at the right time as deferring maintenance works results in a rapid escalation of costs. This will be even more apparent in areas subject to very high rainfall.

A further problem is that maintenance funds are often diverted and spent instead on new construction. The consequences of this can be illustrated by reference to the following example. Assume a national road network of 1 000 km of paved road and 1 000 km of unpaved roads. Based on Table 1, this network will require the following annual maintenance and upgrading expenditure:

paved roads:	$6.0 million
unpaved roads:	$2.5 million

This network therefore requires an annual budget of $8.5 million to cover maintenance and upgrading expenditure alone. If this budget is also used to extend the network by 1 per cent each year, the following will result.

Table 2

	Paved	Unpaved
Annual increase in road length	10 km	10 km
Annual construction cost	$2.5 million	$1.2 million
Balance of budget remaining for maintenance	$3.5 million	$1.3 million
Length of road that can be maintained each year for this sum	583 km	520 km

If this budgetary policy continues for 10 years, 100 km of new paved road and 100 km of new unpaved road will have been provided, but lack of maintenance over this period will have resulted in the following length of the network becoming unserviceable.

Table 3

	Paved	Unpaved
Loss to road network over 10 year period	417 km	480 km
Cost of rehabilitation of unserviceable network	$73.0 million	$21.6 million

Thus, over a 10 year period, the result of adding 200 km of new road has resulted in the loss of nearly 900 km of existing road through lack of maintenance. This is assuming that remaining maintenance funds are concentrated on a restricted network. If the remaining funds were instead spread more thinly over the entire network, the loss of serviceable roads over a 10 year period is likely to be even greater. The analysis in this example takes no account of the additional maintenance requirement of the new roads which imposes an additional burden of $600 000 and $250 000 per year for paved and unpaved roads respectively.

2.1.2 Axle loading

The effect of axle loading and, in particular, of overloaded vehicles on road maintenance requirements is considerable. A 10 tonne axle causes approximately two and a half times as much deterioration to a road as an axle weighing 8 tonnes. More significantly, an axle weighing 16 tonnes does 20 times as much damage as an 8 tonne axle (Transport and Road Research Laboratory 1978). It is clearly necessary, for road maintenance purposes, to know the value of the actual axle loading on a road as minor underestimates can considerably shorten the expected life of a road.

From a road maintenance point of view, there is considerable advantage in having appropriate axle load legislation which is effectively enforced. However, load control is unlikely to be effective if transport rates are controlled by legislation and are such that vehicle operators feel they must overload in order to be competitive. Axle load enforcement must form part of wider legislation dealing with road transport operations as a whole.

There are many problems associated with the enforcement of axle load legislation but, whether axle load limits are enforced or not, the most important thing for the road maintenance organisation is to know the magnitude of the axle loads actually being carried by roads in order that maintenance planning can be carried out effectively.

2.1.3 Lowering vehicle operating costs

Cost savings obtained by deferring the need for rehabilitation exclude the benefits to operators

by avoiding the high cost of operating on badly deteriorated roads. Over the life of a road, vehicle operating costs are typically four times the initial construction cost, whereas maintenance is only one or two per cent of the total road transport cost. If maintenance is neglected, a paved road will crack and pot-holes will start to appear. With this level of deterioration, vehicle operating costs are likely to increase by about 15 per cent. If there is further neglect of maintenance, a paved road will eventually start to disintegrate and vehicle operating costs will increase by about 50 per cent. This is approximately twice the cost of constructing the road. This massive increase in transport cost is many times the cost of road rehabilitation and results from failure to make a relatively small investment in road maintenance.

As an example, TRRL investigated a 100 kilometre length of road in a developing country carrying about 750 vehicles per day. The road had been opened for about four years but, during that time, had received no maintenance. The road was already cracked and deformed, and pot-holes were starting to appear. This deteriorating road condition was already leading to an extra vehicle operating cost estimated to be about $1.5 million per year. A further estimate suggested that, if this situation was allowed to continue, the road would soon start to disintegrate and, in this case, the additional vehicle operating costs were estimated to increase to about $5.0 million per year (Robinson and Roberts 1982). This additional cost would be spent on additional fuel, tyres, spare parts and vehicle replacements, all of which require foreign exchange in most developing countries. Road maintenance, with its relatively high local cost component, can therefore be viewed as a mechanism of import substitution.

2.1.4 Keeping the road open

The third reason for carrying out maintenance is to keep the road open continuously. Roads serve centres of population and industry and, if roads are closed by landslides, culvert washouts, or by the surface becoming impassable during the wet season, then there are potentially serious and economic consequences.

A case has been noted where, in one country during the wet season, 40 per cent of vehicles failed to reach their destinations because of the state of the roads. This resulted in factories having to close for several months because of the failure to get raw materials in and manufactured goods out. Agriculture suffered in a similar way because of lack of fertilisers and the failure to sell produce. If industry and agricultural goods are being produced for export, this has further serious implications for foreign exchange earnings.

2.1.5 Investments in roads

Improvements in road maintenance which reduce vehicle operating costs by between 15 and 50 per cent for the same traffic level, have led to internal rates of return on donor-financed maintenance projects which are generally above 100 per cent. Few maintenance projects have had rates of return as low as 50 per cent, whilst the return on new construction projects rarely exceeds this figure. Feeder road construction projects generally have even lower returns. The high rates of return achieved in maintenance and rehabilitation projects confirms that many roads are in poor condition (Faiz and Harral 1987).

The fact that rehabilitation shows returns which are normally higher than those for new construction corroborates the belief that the roads were initially built using rational selection criteria: projects whose returns were marginal in the past have gradually become justified with economic growth that has resulted in increased traffic. However, the return on new projects is still lower than that being achieved now on those projects that were actually implemented earlier. Existing roads will normally be more important economically than new ones otherwise they would not have been built first. Thus, the maintenance of existing roads should normally have the first call on resources before the building of new roads. Additionally, once construction costs have been sunk in an existing road, the economic return on carrying out maintenance will be very large if this prevents the benefits associated with the road being lost. Even so, it still may not be economic to maintain some low-traffic roads in good condition. A balance must be struck between maintenance expenditures and reductions in vehicle operating costs and, at low traffic levels, the required maintenance expenditures will often outweigh the vehicle operating cost saving derived from the provision of a higher level of service.

Investments in transport are among the highest yield investments available (Robinson *et al.* 1985). This suggests that, if funds are reallocated from other sectors, this should result in an overall increase in benefits to countries' economies as a whole. Normally, projects with the highest benefit should be undertaken first, followed by successively lower benefit projects until funds are exhausted or the benefits of additional projects are below the opportunity cost. However, there are difficulties in comparing the benefits of different types of

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Upgrading aims at providing additional capacity when a road is nearing the end of its design life or because there has been an unforeseen change in use of the road. Typical examples of upgrading projects are the paving of gravel roads, the provision of strengthening overlays for paved roads and the widening of roads.

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Rehabilitation is needed if the road has deteriorated beyond the condition at which overlaying is a satisfactory engineering alternative. This may often be because the road has received insufficient maintenance to enable it to provide an appropriate level of service to the end of its design life. Additionally, rehabilitation may be needed because the original road was not built to the standards of quality required by the original design. Reconstruction to provide a new alignment should be considered as an upgrading project as described above.

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2.1.1 Reducing road deterioration

Even with adequate maintenance, roads will deteriorate over time. The rate of deterioration will depend on a number of factors including traffic loading, road strength and climate. Eventually the end of the design life is reached and there is a need for strengthening or reconstruction. As shown in Table 1, these are very expensive activities and should therefore be postponed for as long as possible by carrying out effective and timely maintenance.

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The effect of axle loading and, in particular, of overloaded vehicles on road maintenance requirements is considerable. A 10 tonne axle causes approximately two and a half times as much deterioration to a road as an axle weighing 8 tonnes. More significantly, an axle weighing 16 tonnes does 20 times as much damage as an 8 tonne axle (Transport and Road Research Laboratory 1978). It is clearly necessary, for road maintenance purposes, to know the value of the actual axle loading on a road as minor underestimates can considerably shorten the expected life of a road.

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There are many problems associated with the enforcement of axle load legislation but, whether axle load limits are enforced or not, the most important thing for the road maintenance organisation is to know the magnitude of the axle loads actually being carried by roads in order that maintenance planning can be carried out effectively.

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As an example, TRRL investigated a 100 kilometre length of road in a developing country carrying about 750 vehicles per day. The road had been opened for about four years but, during that time, had received no maintenance. The road was already cracked and deformed, and pot-holes were starting to appear. This deteriorating road condition was already leading to an extra vehicle operating cost estimated to be about $1.5 million per year. A further estimate suggested that, if this situation was allowed to continue, the road would soon start to disintegrate and, in this case, the additional vehicle operating costs were estimated to increase to about $5.0 million per year (Robinson and Roberts 1982). This additional cost would be spent on additional fuel, tyres, spare parts and vehicle replacements, all of which require foreign exchange in most developing countries. Road maintenance, with its relatively high local cost component, can therefore be viewed as a mechanism of import substitution.

2.1.4 Keeping the road open

The third reason for carrying out maintenance is to keep the road open continuously. Roads serve centres of population and industry and, if roads are closed by landslides, culvert washouts, or by the surface becoming impassable during the wet season, then there are potentially serious and economic consequences.

A case has been noted where, in one country during the wet season, 40 per cent of vehicles failed to reach their destinations because of the state of the roads. This resulted in factories having to close for several months because of the failure to get raw materials in and manufactured goods out. Agriculture suffered in a similar way because of lack of fertilisers and the failure to sell produce. If industry and agricultural goods are being produced for export, this has further serious implications for foreign exchange earnings.

2.1.5 Investments in roads

Improvements in road maintenance which reduce vehicle operating costs by between 15 and 50 per cent for the same traffic level, have led to internal rates of return on donor-financed maintenance projects which are generally above 100 per cent. Few maintenance projects have had rates of return as low as 50 per cent, whilst the return on new construction projects rarely exceeds this figure. Feeder road construction projects generally have even lower returns. The high rates of return achieved in maintenance and rehabilitation projects confirms that many roads are in poor condition (Faiz and Harral 1987).

The fact that rehabilitation shows returns which are normally higher than those for new construction corroborates the belief that the roads were initially built using rational selection criteria: projects whose returns were marginal in the past have gradually become justified with economic growth that has resulted in increased traffic. However, the return on new projects is still lower than that being achieved now on those projects that were actually implemented earlier. Existing roads will normally be more important economically than new ones otherwise they would not have been built first. Thus, the maintenance of existing roads should normally have the first call on resources before the building of new roads. Additionally, once construction costs have been sunk in an existing road, the economic return on carrying out maintenance will be very large if this prevents the benefits associated with the road being lost. Even so, it still may not be economic to maintain some low-traffic roads in good condition. A balance must be struck between maintenance expenditures and reductions in vehicle operating costs and, at low traffic levels, the required maintenance expenditures will often outweigh the vehicle operating cost saving derived from the provision of a higher level of service.

Investments in transport are among the highest yield investments available (Robinson *et al.* 1985). This suggests that, if funds are reallocated from other sectors, this should result in an overall increase in benefits to countries' economies as a whole. Normally, projects with the highest benefit should be undertaken first, followed by successively lower benefit projects until funds are exhausted or the benefits of additional projects are below the opportunity cost. However, there are difficulties in comparing the benefits of different types of

projects from different sectors. For road maintenance projects, with expected rates of return in excess of 100 per cent, even if there is a large shortfall in anticipated benefits, the resulting project is still likely to have a higher rate of return than other transport projects or projects from other sectors.

It is clear from an economic point of view that there is an overwhelming case for carrying out effective and timely road maintenance and that substantially more resources should be devoted to this area.

2.2 ROAD NETWORKS

2.2.1 Network survey results

Developing countries (Faiz and Harral 1987) have a total road network of approximately 1.8 million kilometres of engineered primary and secondary roads of which just over one million kilometres are paved. They have an estimated replacement cost of $300 billion, excluding the cost of land, major earthworks and bridges. In addition, there is a network of low-volume unpaved tertiary roads and tracks comprising some 5 to 6 million kilometres but, because of their lower standards, these have an estimated replacement value of only $75 to $100 billion.

Surveys that have been carried out, principally by the World Bank (Mason *et al.* 1984, Mason 1985, Faiz and Harral 1987), suggest that, of the paved roads in developing countries, only just over 30 per cent are in good condition and more than 25 per cent are in poor condition, requiring rehabilitation. The figures for unpaved primary and secondary roads are even worse, with fewer than 30 per cent being considered to be in good condition and nearly 35 per cent requiring rehabilitation. No figures are available for minor unpaved roads and tracks. Comparative figures for the United Kingdom trunk roads suggest that 85 per cent are in good condition and only 3 per cent require rehabilitation (Standing Committee on Highway Maintenance 1987).

The surveys in developing countries also indicated that there was a backlog of about $41 billion for rehabilitation and that about $4.6 billion a year extra needs spending over the next five years to prevent those parts of the network currently in good or fair condition from deteriorating further. With such a backlog, it is not surprising that the situation is deteriorating. It is difficult to obtain good data to illustrate this because, in most countries, road condition is not monitored on a continuing basis. However, data have been obtained from two countries.

In the first of these countries, detailed measurements of road roughness carried out by TRRL over the period 1978 to 1982 showed that there were increses in roughness ranging from 5 to 17 per cent, depending on the type of pavement construction. In a second country, over the same five year period, paved roads deteriorated from a serviceability index of 3.6 to 3.0 on a scale of 5 (good) to zero (bad). Unpaved roads deteriorated from an index of 3.2 to 1.9 over the same period. The road maintenance organisations in both these countries are fairly efficient and the rate of deterioration is therefore likely to be faster in many other places.

The road maintenance problem has arisen because of a combination of factors (World Bank 1981) and it is convenient to group these under three headings (Robinson *et al.* 1985).

2.2.2 Network and traffic

There have been large increases in the lengths of road networks in developing countries in the last 20 years which have directly increased the road maintenance burden. Roads built at the beginning of the post-colonial period tended to be designed for a 20 year life, whereas, because of financial constraints, roads built more recently have been designed for only 10 years. This has resulted in many roads coming to the ends of their design life at the same time, increasing the need for reconstruction. Traffic growth over this period has been very rapid, and deterioration has been accelerated because of the large numbers of overloaded vehicles.

2.2.3 Funding

In the past, available funds have often been spent on less economic investments both in the road sub-sector and elsewhere. In addition, funds allocated to maintenance have often subsequently been diverted to non maintenance projects. As a result, local funds are now short and foreign exchange is virtually unobtainable in many countries. A further problem is that funding is often irregular which makes planning difficult and uncertain.

2.2.4 Efficiency

There is much evidence to suggest that, even if funding levels were increased dramatically, the level of maintenance that could be carried out would still be limited because of inefficiencies in maintenance organisations. Most organisations have large labour forces which are unproductive

because of poor management, lack of training, lack of incentives and lack of resources to carry out maintenance. This has been compounded because of the failure to establish priorities both by governments and maintenance authorities. There seem to be cultural difficulties resulting in a lack of discipline and poor workmanship not helped by absent or ineffective supervision. Poor attitudes to maintenance are sometimes shown by politicians, planners and engineers who often prefer to be associated with more prestigious construction projects rather than the day-to-day problems of maintenance. The same view can also be seen among donors. In many developing countries, there are still shortages of skilled personnel despite considerable past efforts with technical assistance and training. Maintenance is normally carried out by the public sector which, because of low salaries and lack of pay incentives, compared with local industry, often finds it difficult to attract and retain high quality staff. There is also frequent reassignment of staff because of political and administrative changes. Equipment availabilities have been found to be generally very low, with the result that the costs of using equipment are unnecessarily high. All of these factors combine together to result in low output.

2.3 DONOR ACTIVITY

2.3.1 The Paris consensus

Concern over the road maintenance problem led the World Bank to call a meeting in Paris in February 1980 to exchange views on the difficulties faced by developing countries and development aid agencies in the field of road maintenance, and to seek consensus, wherever appropriate, on ways to overcome these difficulties. The meeting was attended by representatives of most of the major aid donors and the following eight-point action plan was considered (World Bank 1981).

(i) **Periodic maintenance** would be eligible for aid funding in the case of the poorest countries;

(ii) **Routine maintenance** should be eligible for funding under certain circumstances and in the poorest countries;

(iii) **Spare parts** were seen as essential and should be funded, with encouragement for the countries concerned to build up their own capacity to finance spares through such mechanisms as plant hire schemes;

(iv) **Equipment** should be delivered and operated through aid projects in such a way as to minimise the financial burden of replacement and with the object of developing countries eventually financing replacement from their own resources;

(v) **Training** was to be given priority, preferably through financial grants;

(vi) **Reconstruction** of roads would be funded only where reasonable preventative maintenance had been done;

(vii) **Maintenance and maintenance capability** would be reviewed in connection with any new construction project, and aid agencies would coordinate their efforts to encourage better maintenance throughout the entire highways subsector; and

(viii) **Private contractors** were to be encouraged to develop by employing them under proper supervision on a range of road maintenance tasks, with experiments to determine the best procedures in each country. Aid agencies were to develop means of assisting contractor development through highway authorities or development banks or both.

2.3.2 Progress since Paris

The Paris initiative was timely and the concerns being expressed by several developing countries and aid donors about the poor state of road maintenance resulted in positive changes being made. Several of the bilateral and multilateral donors attending the meeting effected changes in their lending policies to enable aid for road maintenance to be provided. However, it is difficult to escape the conclusion that those policy changes have had only a small effect on the aid disbursed since the Paris meeting. The majority of road subsector aid is still spent on new construction and, of the remaining amount, the vast proportion is spent on rehabilitation rather than on maintenance.

Attempts have been made to develop awareness of the problem by holding regional seminars and conferences specifically devoted to the road maintenance problem in Asia, Africa and Latin America. In addition to these regional activities, other meetings have taken place in individual countries. Both the World Bank (1981) and the IRF (undated) have prepared pamphlets aimed at senior policy makers and have produced these in several languages free of charge. Initiatives have also been taken to provide maintenance workers with manuals to assist them in their day-to-day operations. The United Nations Economic Commission for Africa (1982) with the co-operation of France, the Federal Republic of Germany and the United Kingdom, have produced a handbook for road maintenance foremen and have provided 20 000 free copies for African countries. As mentioned earlier, TRRL have produced two manuals for district engineers and these have also been made freely available to all developing countries (TRRL Overseas Unit 1987, 1985). In addition, ESCAP

(1981) have produced a maintenance manual for use in South East Asia. More recently, IRF have produced a series of video training aids aimed at improving road maintenance operations in developing countries.

However, even in those countries which have shown a determination to overcome their maintenance problems, the world economic recession of 1980–2 has thwarted their endeavours and this is particularly apparent in Africa (World Bank 1984). Whereas, for industrialised countries, GNP rose by 2.3 per cent in 1983 following a fall of 0.1 per cent in 1982, this recovery has not been reflected in Sub-Saharan Africa, even in those countries with the best earlier records. For oil importers, per capita output fell by 0.9 per cent in 1981 and 1.7 per cent in 1982, but there was no recovery in 1983 when per capita output fell by a further 2 per cent. Neither did developing countries benefit from the 1983 recovery. In these circumstances, countries find it difficult to provide the additional resources that are necessary to revitalise activity in the roads subsector.

In recent years, donors have experienced more difficulties with project implementation. Various reasons account for this. More projects have been directed towards maintenance instead of new construction and are therefore more complex, requiring a greater administrative effort. The limited institutional capability in recipient countries has made it particularly difficult to cope with the more complex projects. In addition, shortage of government funds has sometimes resulted in the execution of projects being stopped or sometimes delayed in an unsystematic and costly way. Indeed, even institutions which had been well funded and had operated well in the past have started to deteriorate due to poor economic conditions. The result is that many projects are merely reducing the rate of road deterioration, rather than achieving positive improvements to networks as a whole.

The aid donors met again in 1985 in London to review progress since the Paris meeting. Whereas the theme for the Paris meeting had been the 'road maintenance problem' (World Bank 1981), delegates now found themselves discussing the 'road maintenance crisis' (Robinson *et al.* 1985).

2.4 MAINTENANCE IMPLEMENTATION METHODS

2.4.1 Achieving benefits

Many countries are incurring high economic costs because of inadequate road maintenance (Faiz and Harral 1987). Large potential benefits are available as a result of improving the standard of maintenance but, for these expected benefits to be obtained, it is necessary for maintenance to be:

(a) carried out to a sufficiently high standard to achieve the required improvement in pavement condition;
(b) durable, so that the maintenance input is effective for a sufficiently long period;
(c) efficiently carried out so that the cost is of the expected order.

Unfortunately, road maintenance operations very often fall far short of these requirements. The solution to this is not just a question of putting more money into maintenance, although this is usually needed. There are severe constraints to carrying out effective maintenance caused by bureaucratic procedures, lack of management skills, low availability and utilisation of maintenance equipment and, most of all, by attitudes to maintenance.

To achieve greater efficiency and productivity from road maintenance activities, there is a need to introduce an organisational structure, from the highest levels of government downwards, which will enable the available resources to be applied most effectively to the tasks that are to be accomplished.

2.4.2 Organisation of work in the maintenance department

The organisation of work within a maintenance department is affected by fundamental decisions such as (a) the use of direct labour or contractors, and (b) equipment based or labour intensive maintenance methods. These will be discussed in Sections 2.4.4–2.4.6.

The organisational structure and management methods used within a maintenance department (World Bank 1981) should be such that they result in the delegation of authority *and* responsibility to the lowest possible level. This should result in a much more efficient organisation and will reduce considerably duplication of work by senior staff. The level of delegation should be limited only by the availability of trained staff and the minimum size of working unit that is viable. Routine and recurrent maintenance operations and management should normally be decentralised as much as possible and the maintenance engineer must ensure that the location and deployment of his maintenance crews is best arranged to meet his district's maintenance requirements. If they are not, he should recommend changes to his head-quarters. To be effective, delegation must be supported by a good system of communication

and inspection. In practice, this is more dependent on good inspector training than on written reporting procedures. The criterion for success should be the quality and quantity of work actually completed. This can only be assessed properly by field visits and inspections by supervisory staff, including senior staff from headquarters. Subject to such field inspections and general supervision by headquarters staff, engineers and supervisors in charge of maintenance units should normally be allowed considerable freedom of action.

The management of maintenance at all levels requires appropriate skills which can only be developed by proper training. The provision of well-designed courses on road maintenance and management is necessary in all road maintenance organisations.

2.4.3 Appropriate design and control of construction

From overseas studies carried out by TRRL, it is becoming increasingly clear that there is considerable scope for improving the standards of quality control during the construction of roads and that this will later pay high dividends in increased durability. Similarly, money spent initially on good drainage structures can save expensive renovation later, and this is particularly true in high rainfall areas.

Recently, concrete roads have been attracting a great deal of attention in the search for 'maintenance-free' roads and the evidence from a preliminary survey of a number of countries (Parry 1985) suggests that, although the construction cost of bituminous roads is usually less, the difference between the two materials is small. However, concrete has often been shown to be more durable, producing a better long-term road base and requiring initially less maintenance than bituminous surfaced roads. Many developing countries can now produce their own cement with a resulting saving in oil imports. Knowledge of concrete technology is reasonably widespread in developing countries, and the construction of concrete roads can often be subcontracted to small local operators. Concrete has been found to be particularly useful in areas subject to repeated flooding and on steep slopes. Studies are currently being undertaken by TRRL Overseas Unit to construct and monitor trial sections of concrete roads in tropical environments to assess their long term performance.

A study by TRRL (Rwebangira and Rolt 1984) also suggests that, for bituminous pavements which have bases that are not water susceptible (i.e. stabilised, etc.), a limited amount of overdesign of pavement thickness may be justified to compensate for the subgrade becoming saturated with water because of poor maintenance. The overdesign is justified in terms of saving in total transport costs over the life of the road. This conclusion does not extend to roads with bases that are seriously weakened by the ingress of water caused by poor maintenance.

2.4.4 Maintenance equipment

Poor availability of equipment is almost always a factor in maintenance organisations that are inefficient (World Bank 1981). Studies have shown that it is common for average equipment availability to be of the order of 10 per cent for motor graders and 30 per cent for agricultural tractors. (Edmonds and De Veen 1982, Roberts and Gaituah 1983, Mason 1985). This is based on availability measured simply as the proportion of working days that the equipment is in a suitable condition to work. Clearly the actual utilisation of equipment is constrained by its availability. In many maintenance organisations, the true costs of owning equipment, particularly of equipment standing idle, are not well understood.

Low availability of equipment is a major factor in limiting the amount of maintenance undertaken. A further difficulty is that there is usually considerable interdependence between machines; if one breaks down, then others may stand idle. With such low efficiency, investment in equipment is very costly in relation to the amount of maintenance which is accomplished. Because of this, it is desirable to concentrate equipment on the tasks for which there are not satisfactory alternative techniques. Steps should then be taken to support this essential equipment more effectively so that its availability can be improved.

There is some advantage in having a separate 'equipment division' or 'mechanical branch' within a maintenance department (World Bank 1981) which is entirely responsible for all aspects of equipment, including procurement, the supply of spare parts and repairs. Such an organisation would usually have its own sub-divisions in the field and regional workshops. Ideally the organisation would finance replacement equipment through a 'revolving fund'. However, the establishment of such 'plant hire departments' requires considerable additional management inputs, calling on skills which are usually in very short supply. Moreover the purchase of spare parts and replacement equipment requires foreign exchange which is often scarce and cannot be realistically generated within the hire system, even though the required amount of local currency may be generated by the hire charges.

2.4.5 Labour-based maintenance

The lack of equipment, or working equipment, is often a major constraint on executing maintenance (Edmonds and De Veen 1982). Equipment is expensive and consumes fuel and spare parts which have to be purchased with foreign exchange. Equipment requires skilled operators and skilled mechanics. If any of these is not available, then the equipment stands idle and maintenance cannot be carried out.

By contrast, labour is often readily available and its employment usually involves a very low opportunity cost. Moreover, labour-based techniques are suitable for a number of maintenance activities. Extensive studies have shown that for such activities labour-based methods are likely to be cheaper than those based on equipment where the labour rate is less than about $4 per day (Sud *et al.* 1976). In addition, other studies have shown that labour is generally far more reliable than equipment in developing countries. Particularly when managed on a task work basis, labourers have been found to achieve close to planned standards of productivity, whereas accomplishment by equipment usually falls far short.

Thus, road maintenance offers considerable scope for using labour and this can be particularly useful and cost-effective if equipment availability is low. Table 8.1 of Overseas Road Note 1 (TRRL Overseas Unit 1987) indicates which activities are best carried out by labour or equipment.

In many cases, the costs of labour-based operations can be competitive with those for operations carried out using equipment and, for most activities, the quality of the finished work can be comparable. However, the quality and productivity of labour-based work is very dependent on the quality of supervision and supervisors need to be specially trained to acquire the skills needed to supervise large labour forces.

The choice between equipment and labour-based methods affects the basic organisation of road maintenance. Equipment intensive works favour a more centralised organisation, whereas labour intensive works favour de-centralisation. If labour-based methods are to be used, other changes are also needed in the organisation of work. It is important that good work procedures are established and that the correct tools are available for the job. If labour is expected to work efficiently, appropriate tools of an acceptable quality must be provided.

2.4.6 Use of contractors

In most government organisations, it is difficult to provide work incentives and this is particularly true in a road maintenance department. The result is that work is often carried out inefficiently and the quality and quantity of output is lower than it could be. One way of obtaining greater efficiency is to make more use of contractors. (Harral *et al.* 1982).

In many countries, periodic maintenance activities such as surface dressing and regravelling have traditionally been carried out by contract. Contractors have also been used for the supply and haulage of gravel and aggregate, as well as for carrying out construction and minor improvement works. It is possible to carry out routine and recurrent maintenance by contract, but the work can be more difficult to specify and monitor. For such operations, it may be necessary to specify total amounts of work per kilometre of road for each maintenance activity, with emergency repairs being paid for at daywork rates. Proper supervision is vital for all contract work. Specifications should be used, and checks made to ensure that they are complied with.

There are several advantages of using contractors for maintenance work. Contractors may achieve greater efficiency and lower costs because of competitive pressures which are unlikely to be present in a government organisation. The use of contractors changes the organisational and management burden on maintenance departments and this system of working also reduces the possibility of maintenance resources being diverted to non-legitimate activities. Maintenance contracts can also be useful in encouraging the local contracting industry and in providing an introduction to work in the roads sector.

However, there is sometimes a danger that contractors bidding for maintenance work on a regular basis might introduce 'price-fixing' in order to increase their profitability and this will result in an increased cost to the maintenance department. It is also important to ensure that contractors appointed do in fact have the capability to actually carry out the activities for which they have bid.

If maintenance is to be carried out by contract, then this will affect the size and skills required of the maintenance organisation considerably. However, the approach is worth considering as a possible way of increasing the effectiveness of road maintenance activities.

A further option is for the ministry's works department to operate as a contractor bidding against conventional contractors for work that is placed by the maintenance department. Such a system has been introduced successfully in the United Kingdom. This removes the monopoly of the maintenance organisation and ensures that price-fixing between contractors cannot be successful. The change required of

the maintenance organisation is much less traumatic than if it were to rely completely on contractors, but it is important that the organisation takes all of its operating costs fully into account when bidding for work.

2.5 BUDGETING FOR MAINTENANCE

Raising money for road maintenance is often a major problem (World Bank 1981). Politicians often seek prestige by constructing new works and planners often favour capital projects because they have easily measurable development benefits. Furthermore, senior engineers in the highway department often themselves prefer that the emphasis of effort should be on new construction rather than maintenance. In addition, new construction is often financed externally under aid, whereas maintenance must often be funded locally. The result is that, in most countries, the maintenance budget is determined by the residual funds in the highways budget after the construction budget has been allocated. However, for maintenance to be really effective, it requires sufficient funds that can be spent steadily on a long-term basis. Roads departments in all countries of the world have an obligation to spend their budgets effectively and in such a way as to achieve best value for money. However, constraints on the resources available make it necessary to set priorities for budget allocations and these are needed at all levels in the hierarchy from national to local level.

The first objective is to set priorities at a national level and this will usually be done by a government minister or at the most senior level in the roads department. All countries have a considerable investment in road infrastructure and the first objective must be to preserve this existing investment and to stop its value declining. This can be achieved only by providing appropriate, effective and timely maintenance. This should therefore be the first priority for budget allocation. At present, many countries are not providing even this basic maintenance for much of the road network. In this situation it is necessary that the most important roads are identified so that maintenance resources can be concentrated to ensure that effective maintenance is carried out at least on the parts of the network where it will bring the greatest benefit. In the absence of more detailed information, the amount of traffic on each road can be taken as an indication of its relative economic importance.

Having allocated funds in order to preserve the existing system, the next objective should be to try and maximise the return on this investment. This can be achieved by upgrading and improving elements in the road system. Improvements to the geometry and the structural strength of roads will lead to more efficient traffic operation and to a reduction in maintenance expenditure in the future.

Only after funds have been allocated for maintenance and upgrading, should any remaining part of the budget be allocated for new investment. There is no point in investing in new roads if, by doing this, effective funding of road maintenance has to be reduced. This will result in a decline in the serviceability of the existing road system caused by the construction of extensions to the system.

It is necessary to pin-point the responsibility for maintenance very precisely as this is the only way to ensure that resources are not diverted to other areas. For this reason, it is best if maintenance is the sole responsibility of a separate government department or, at the very least, a separate department within the roads organisation (World Bank 1981). In either case, it should have its own budget which cannot be diverted to other activities. In some countries, use is made of 'earmarked taxes' which are paid directly to the road maintenance department for their exclusive use. These taxes can come from any source, but the easiest to administer are fuel and vehicle import taxes. With either of these taxes, there is little chance of evasion. Fuel tax has the added advantage that the charge levied is related to vehicle use and hence, to some extent, to the road deterioration caused by the vehicle.

In order to assure an adequate budget for maintenance, politicians, planners and senior engineers should be made aware of the need for maintenance and particularly of the consequences of deferring maintenance or not carrying it out at all. Senior departmental staff should also press for changes to the structure of government departments to enable appropriate and effective organisational and funding arrangements to be adopted.

3 MAINTENANCE PROJECT IMPLEMENTATION

3.1 THE EMERGENCE OF MAINTENANCE PROJECTS

Most developing countries have placed considerable emphasis on extending and improving their road networks during the post-colonial era as this has rightly been seen as an essential component of a comprehensive development programme. Developing countries are still spending over $10 billion each year in the road subsector, mostly on new construction and improvements (Faiz and Harral 1987). In the past, both

bilateral and multilateral aid donors have given enthusiastic support to such infrastructure development since economic returns were thought to be easy to predict, have a good chance of being realised and, if carried out by expatriate consultants and contractors, were relatively easy and cheap to administer.

Until the start of this decade, projects for road maintenance were seldom undertaken by donors because it was claimed that support of recurrent expenditure did not contribute to real long term economic and social development. However, the recognition by both developing country governments and donors of the technical and economic importance of road maintenance, as described in Section 1.1, led to a change in the balance of the type of projects undertaken in the road subsector. Over the past few years, emphasis has moved away from capital schemes and towards projects for road maintenance.

3.2 TYPES OF MAINTENANCE PROJECT

Maintenance projects can be very varied, but generally fall into two groups (Robinson 1984). The first has the objective of building up the institutional capability of the organisation to carry out maintenance for itself in an efficient manner. The second form of project has the objective of overcoming a short-term problem and includes such items as the supply of maintenance equipment or spare parts, surface dressing or regravelling a particular length of road by contract, or provision of specialist courses or technical assistance. The second type of project may be one component of the first type of project.

Most maintenance projects will be attempting to rectify fundamental institutional problems of a maintenance organisation with the objective of increasing the general capability or, perhaps, the capability in some specific area. Lack of capability will often result from the institutional situation, plus lack of management, technical skills, insufficient resources and lack of foreign exchange. If lack of maintenance has resulted in badly deteriorated roads then, because the cost of construction is already 'sunk' and the possible savings in vehicle operating costs and deferred reconstruction are high, the potential return from road maintenance projects can be extremely large. However, the difficulty of realising these benefits, in practice, is considerable.

The time horizon for institution building projects needs to be long (Robinson 1984). It is unrealistic to expect to make fundamental changes to the workings of an organisation which are sustainable in less than about 10 years. Often, organisational changes are needed that go right to the heart of government and these will be very difficult to arrange. The fundamental problem behind lack of resources may be that the macro-economic performance of the country is insufficient to generate the foreign exchange that is needed. The lack of trained staff may be due to an insufficient number of students graduating from schools, colleges and universities, or may be due to the lack of a work situation in which training can develop. It may also be due to an inadequate wage structure. Often a combination of several problems will apply simultaneously.

Proposals for tackling institutional aspects of maintenance should be examined to ensure that they are tackling the root cause of lack of capability. Well-founded projects may be in operation for several years before any measurable improvement in maintenance capability can be observed. This must be clearly understood, not only by those promoting and funding the project, but also by the organisation responsible for executing the project. It can be expected that the final benefits may be substantially lower than those predicted, and this should be taken into account when feasibility is being assessed by carrying out sensitivity or scenario analysis.

The second type of project is usually easier to define and the work is relatively straightforward to execute and monitor. Benefits, and the probability of achieving the benefits, should be relatively easy to predict. However, there is a danger that this type of project will only remedy the symptoms of a problem and will do very little to rectify the cause, which will often be institutional constraints on the general capability to carry out maintenance. Short-term maintenance projects will only be appropriate in a very few cases and proposals in which they are recommended should be vetted very carefully to ensure that a deep-rooted and long-term problem is not being tackled with short-term measures.

3.3 STUDY OF MAINTENANCE MANAGEMENT PROJECTS

3.3.1 Background to the study

In their publication 'The road maintenance problem and international assistance', the World Bank makes the following observation (World Bank 1981):

"A great deal of emphasis has been placed in many Bank-assisted projects on the application of modern management systems for planning, programming, budgeting, scheduling, control, and data collection, and it is difficult to avoid the conclusion that it has often been overdone. In some instances, the management

information systems introduced by consultants have simply proved too complex to function or to be used beyond headquarters. In others, they were excessively dependent on computers that were unavailable or functioned poorly. More often, elaborate reports have continued to be produced at lower levels of the hierarchy, but there has been no effective system for checking them, and they have been little used, for lack of qualified headquarters personnel to handle them or for lack of interest. The effort seems to have been spread over too many systems, with too much detail, and with insufficient attention to the structural constraints on the ability of management to act."

Against this background, the Overseas Unit of TRRL were asked by the Overseas Development Administration to carry out a study of maintenance management projects to try and identify why problems arose with implementation and to recommend ways of overcoming these. The study consisted of two parts. The first reviewed available published and unpublished information on projects. The second part involved TRRL staff working alongside consultants engaged on contracts to implement maintenance management systems in developing countries.

It is inevitable that the results of this study are sensitive and, as a result, have not been published in full. In this report, an attempt is made to highlight the main results of the study without indicating directly or indirectly which countries and which consultants were involved. An attempt has also been made to draw conclusions from the findings and to recommend a method of assessing the type of assistance most appropriate to a particular set of circumstances.

3.3.2 Published information

In July 1985 at the PTRC Summer Annual Meeting held at the University of Sussex in England, a one day seminar was held on road maintenance management in developing countries (PTRC 1985). The organisers were concerned that, whenever the implementation of maintenance management systems in developing countries was reported in journals or conference proceedings, consultants and developing country governments presented a picture of success that was not consistent with the observations of the World Bank quoted above. Not surprisingly, neither consultants nor governments wished to advertise failure and there was a belief that published papers either deliberately avoided mention of problems that had arisen on projects or, even worse, mis-represented the outcome of events.

Ten international consultants who had been engaged on maintenance projects were invited to talk frankly about the problems that they had encountered during implementation so that mistakes would not be repeated in the future. Unfortunately, several of the consultants chose to report and present bland success stories in the seminar, despite admitting privately that their projects had encountered many problems and that not all objectives had been achieved. However, some of the consultants were frank about problems that had arisen and were keen to share their experiences with others present. A further seminar was held the following year (PTRC 1986) and some additional information was obtained.

The following problems were raised by the various consultants in these two seminars. Extracts from the consultants' papers are quoted. Some information has been substituted in brackets to preserve anonymity.

Terms of reference

"(The client, the donor and the consultants) were all wrong to accept without question a concept which, be it said had been originally conceived by personnel in the (donor organisation) and in (the recipient ministry) who were long gone. The present personalities in all the organisations concerned are the third generation and therefore continuity has been a problem throughout."

"There is some doubt as to whether such a comprehensive programme was indeed appropriate to (the country's) needs. While it was true that practically all areas of highway maintenance required revision and assistance of some type, with hindsight it can be said that a programme addressing all such issues, however structured and well planned, would be unlikely to succeed."

Client attitudes

". . . top management did not feel that they had any need for technical assistance to improve their administrative procedures or that they needed institutional strengthening. The (donor) felt that they did have these needs, and consequently technical assistance was made a component of the . . . loan. . . . The consultant was placed in an adversary situation from the very beginning of the project."

"The role of the consultants and technical assistance were ambiguous. (The client) never provided the managerial support necessary to implement the systems. The (donor and the client) both held the consultants responsible for the success of the programme, but in practice the consultants were powerless to effect change unless (the client) supported it at all levels. The consultants were ultimately only advisers. In these circumstances, a less comprehensive programme might have stood a greater chance of overall success."

"In addition, (the client) had clear prejudices and expectations about technical assistance. The first was the suspicion that the consultants could not be totally loyal. . . . This, in turn, led to them being excluded from the real politics of the maintenance department who disguised key issues. In addition, high technology solutions were expected even when the appropriate remedies were simply based on

common sense. These expectations and general feelings of unease increased as counterpart . . . staff salaries fell and consultant salaries increased in terms of local currency. Finally, the consulting staff could only offer advice, and there was no possibility of acceptance until (the client was) convinced of its appropriateness. This risk is taken by all consultants, but a different programme structure could have ensured that recommendations were considered promptly and accepted or rejected on merit instead of being ignored."

"Resistance to change in management practices was stronger than expected, even when procedures were being introduced for the first time. The status quo was fiercely defended and it was difficult to get new practices adopted, even where advantages were obvious."

"Resistance to change was perhaps the most difficult obstacle to overcome. The maintenance system . . . had evolved over many years, and (local) staff saw their chief problem as lack of resources — equipment, materials and funds — not maintenance management. Thousands of jobs were involved. Promotion depended on a well understood system, and district loyalty was frequently stronger than headquarter's policy. These issues meant that it was unlikely a comprehensive revision of maintenance procedures could be achieved in so short a time."

Cultural issues

"The first is the fact that most traditional (developing country) societies are essentially gerontocracies: a man's authority goes with his age. Naturally, when localisation took place, it was usually young men who had the overseas, professional training, and were therefore rapidly promoted to senior positions. Thus their natural lack of confidence in making important decisions, because of inexperience, was further amplified by the virtual impossibility of giving an executive instruction to subordinates who were frequently older, and insisting that the instructions are carried out."

"The second characteristic of (developing) countries affecting management efficiency is that they are nearly all multi-(cultural). This means that to the difficulties of giving orders to older subordinates are added the problems inherent in giving orders to members of another (culture)."

"Any highway maintenance organisation is a complex pyramidical management structure, in the normal pattern taken for granted in an industrialised . . . country. This type of management structure is utterly dependent on instructions being passed down the line, sensibly interpreted in detail at each level, and passed down, in the sure knowledge that they will be carried out. There is, of course, a disciplinary system to back up the orders, but this is normally taken to be a last resort only. However, the knowledge that disciplinary measures can, if necessary, be invoked is naturally an incentive for good operational efficiency, coupled with the more positive incentive of promotion depending on good performance. If traditional considerations make the incentives ineffective, management efficiency . . . is severely impaired."

"In practice, of course, situations on the ground are frequently such that excuses can be found for inefficiency, which tend to obscure the basic problems of management. No attempt to deal with the problems will be truly successful which does not take full account of these traditional behaviour limitations."

". . . staff assessment seems to be the only real means of showing to the man and to his superiors that he is worthy of promotion. Without it, nepotism and favouritism could well be perpetuated to the detriment of staff morale and efficiency."

Staffing of teams

"A central difficulty, never fully resolved, was the staffing of technical assistance consultants. The initiation of the project was delayed for over a year. The consultant staff originally proposed for the project made other commitments. Low consultant salaries plus the worsening economic conditions (locally) made it difficult to attract qualified experts. Since the elements of the programme were interrelated, delays in filling positions and poor performance in those positions made it certain that the balance of the programme would be affected."

"That not all the aims of the study will have been adequately covered can be blamed largely on two misguided assumptions:

- three disparate individuals, one consultant, one (contract) expatriate and one national, will immediately form a workable team.
- The team leader would be able to study, design, modify and report on systems, while implementing them with the other hand."

Economic and financial problems

"If the (local) currency had not weakened so rapidly, the maintenance programme might have been able to accommodate the delays. However, the severity of the economic crisis and the consequential effect on (local) staff morale and efficiency had serious impacts on the project. It is not possible, of course, to guarantee financial stability over a project life or to develop a programme that can accommodate the changes in economic performance, but the programme would have benefited by explicitly stating the local currency equivalents in (foreign currency) and specifying the need for monetary correction, if justified. In addition, it would have been useful to structure the programme so that it could be more easily redirected as new problems emerged and potential solutions presented themselves."

"The . . . economy, relatively stable throughout the 1970s, began to seriously weaken soon after the maintenance programme was started. Falling prices for its . . . exports on the international market combined with high . . . interest rates made it difficult for the government to repay the foreign loans taken out by previous administrations. . . . Government policies were ineffectual in resolving the key issues affecting the strength of the . . . economy which resulted in high domestic inflation, unemployment and an irresistible pressure to devalue. When the government refused to devalue, a black market resulted and eventually official adjustment had to follow. This caused a number of problems, especially for project funding in local currency, since there was no official link to (foreign currency) in the programme design, nothing was in

writing which made it difficult for (the client) to go back to the (ministry of finance) for additional local funding."

"The economic difficulties seriously affected . . . counterpart staff morale, causing a preoccupation with issues outside the maintenance programme. . . . Important counterpart contributions to elements of the programme were lost and deadlines missed. . . . Project products were formulated without any collaboration between (local) staff and technical consultants."

"Bitumen and crushed gravel shortages slowed the deferred maintenance programme. All bitumen was imported, and this required scarce foreign exchange which was not promptly available, resulting in long delays. (Donor) finances could not be allocated to the purchase of materials, so elements of the programme dependent on this item themselves became delayed. Crushed stone was not always available in the quantities required even though equipment for its production was specially purchased. The crushing plants required considerable start up time. Government . . . policy precluded double work shifts so nearly half of each work day was devoted to getting the crusher plants operational. Operating time was curtailed further since half of the first and last day of each week was allocated to travel time to and from the crushing plant locations. Finally, inadequately trained operators misused the equipment resulting in frequent breakdowns that took days to correct. The resulting monthly crush stone production was only a fraction of that planned when the equipment was acquired."

Staff availability

"Staffing difficulties already identified caused the programme to change and many positions were never filled."

"The availability of staff for re-training and upgrading was limited by operational needs and turnover. There was a high percentage turnover of engineers, technicians and skilled operatives. In most cases, experience had been replaced with inexperience and there remained a continuing and substantial deficiency of establishment. The shortage of technically skilled staff was exacerbated by a policy of leaving posts open, i.e. unfilled, for staff who left the (client's organisation) to work overseas."

"The staffing deficiencies in the . . . districts were such that some of the functions of project preparation could not be executed. There was also a considered imbalance between districts in the provision of engineers and technicians."

Staff training

"Much classroom training has been carried out, but there has been very little follow-up revision in the classroom, and on-the-job training and assessment."

"Problems in developing the major elements of the programme such as the maintenance management system and the equipment management system resulted in delayed training causing dissemination of proposals through the (client's) structure to be impeded. Training was correctly identified as a major issue, but in practice it was found difficult to co-ordinate the elements of training programmes in the method devised by the planners of the maintenance project."

"There was a lack of direct contact between the training centre management and that of the districts, a lack of 'follow-up' after courses, planned on the job training, and planned work experience. Graduate training was over-ambitious and instructors inadequately prepared. Optimum use was not being made of the existing training facilities."

Equipment

"The maintenance programme called for new equipment together with technical assistance. It was rather unfortunate that they actually came in that order. The new equipment and spares were quickly put into the three districts but into the existing traditional maintenance system. Immediately an effect was felt, and an improvement in performance was obvious. This lessened the chance that technical assistance would be successful. Change is so painful, why bother when new equipment alone has already achieved such an improvement? By timing the programme inputs in this way, the impact of the consultant's recommendations was less likely to have the desired effect on changing existing practices."

"A considerable amount and range of equipment was being acquired with (donor) assistance, but the . . . counterpart staff were concerned that consideration had not been given to its maintenance and repair, and at their instigation the existing facilities in the districts for routine servicing and centrally for major servicing, and repairs were assessed. From a cursory inspection it was plain that the facilities were inadequate in every respect."

Computers

"Computer assistance was to be a key element in the programme. Inventory systems, cost schedules, programme evaluations, rental rates and so on all need computing services to be handled efficiently. In-house computer faciities were assumed to be adequate but in fact were deficient. Funds allocated for consulting staff salaries were used to purchase and ship a mini-computer and line printer capable of handling all reports, procedures and evaluations."

Data availability

"Data availability was underestimated and this was significant given the need to plan maintenance activities on current information. Frequently little or no data existed, and a specific resource had to be directed to their collection. It was more troublesome to collect certain data that, at least in theory, were available through existing channels. Sometimes they were the wrong kind of data, and frequently it took time to disentangle what was required from what had been collected. It was always difficult to do this with historic data, and it was not always possible to check with the person or organization responsible for their collection."

Post-project situation

". . . the programme of technical assistance for maintenance . . . was not a success. The latest information . . . indicates that economic conditions . . . have deteriorated further following the departure of the consultant. None of the procedures developed and implemented during the study period are currently being used. The computer hardware acquired with loan funds is not in operation because

(the client) does not have the personnel qualified to operate this equipment."

". . . operation has been handed over from the (research division) . . . to the Maintenance Division signalling its acceptance as a standard maintenance tool. With this move a potential problem has, however, occurred as there has been no parallel transfer of the key personnel trained by the consultants. It is also interesting to note that (the survey control unit) has not been set up as a separate entity though it is believed that the Department's Training Division has established a framework for the future training of survey staff. The teams that have been used to collect visual condition data for the network wide expansion of the system have been trained by (staff), who had themselves received one week's training from the consultants. With this level of training it is necessary for a centrally controlled unit to monitor continuously the quality of the data collected . . ."

"On the departure of expatriate maintenance engineers, both civil and mechanical, as part of 'localisation' programmes, relatively young and inexperienced local engineers were quickly promoted to fill the vacant posts. In some cases the management problems which they would expect to have to deal with have been compounded by political or security problems, and by the added attractiveness of the private sector, or even overseas employment, which have left the road maintenance organisations severely short-staffed at senior management level."

3.3.3 The TRRL field investigation

Rather than describe in detail the TRRL field study, a situation is described, which includes the main features of the projects. It is believed that this is representative of many projects to implement maintenance management systems that have been carried out in developing countries.

The implementation of the management system was divided into several phases to try and ensure that the introduction took place in a systematic way, with each phase being completed successfully before the next was attempted. This also enabled modifications to be made to the system to ensure that it was entirely appropriate for local conditions and that it met all the requirements of the client. Although the centrepiece of the management system was the suite of computer programs mounted on a microcomputer, most of the emphasis during the implementation stage was on training of local staff in field inspections and data collection. This was in accordance with recommendations made by both TRRL and the donor.

The following problems were encountered with the system implementation.

1. The system needed to fit in with the budgetary requirements of the client. In particular, there was a particular requirement for the budgets to be divided between recurrent and capital based on the size of the area of road requiring treatment. This was felt by the consultant to be irrational. Although this requirement was met by modifications to the system, it resulted in a method of maintenance management and allocating funds that was thought to be unhelpful.

2. Staff in the districts who were concerned with maintenance considered themselves to be overburdened with bureaucratic tasks and overworked. Whether or not this was actually true is a matter for conjecture, but nevertheless it was a view that was firmly held. Given this situation, the introduction of additional tasks connected with the management system were unwelcome. In particular, technicians who should have been responsible for leading the inspection teams were reluctant to leave their air-conditioned offices and walk the road network for which they had a responsibility for taking measurements. It became apparent later in the study that, immediately after training, the technicians had delegated the survey work to more junior, and possibly untrained, staff.

A further responsibility of these technicians was to supervise actual maintenance works. It was also clear that this did not happen, and a senior member of the client's staff stated, only partly joking, that 'maintenance works were supervised by the driver!'. Although it is easy to blame the technicians for their failure, if the district engineer had been doing his job properly, he would have been making spot checks of his field teams and realised that the proper supervisors were not on site. Similarly, lack of supervision by headquarters staff contributed to the inadequate peformance of the district engineer. There was clearly a reluctance of staff at all levels to get out into the field. The result was that much of the field inspection, which was one of the key elements of the management system, was being carried out by staff who had not received training appropriate to the task that they were carrying out. Although this problem had been anticipated by the consultants, the choice of staff to be trained was made by the client and the consultant had little influence on their selection.

3. The consultants recommended at the start of the study that a system manager should be appointed. Although an engineer within the headquarters organisation was designated to this position, the task was in addition to all of his existing duties and he clearly believed that it placed an unrealistic burden upon him. Whether or not this was true, the result was that the system manager played little active part either in supervision of activities in the field or in

checking the computer input process. The latter activity was delegated firstly to a computer operator and then to a junior engineer working, as a result, without effective supervision.

4. A particular problem arose because the client's project officer had a rather different view of what to expect from a maintenance management system than the consultant was proposing, despite this being clearly stated in the Terms of Reference and the Proposal. This led to considerable misunderstandings between client and consultant and contributed to the difficulties experienced by the project at various stages.

5. The final phase of the study was to extend the management system from the pilot district to the whole of the country. During the previous phases, the consultants, assisted by TRRL, made recommendations about how this should be done. There was clearly a political necessity within the country to achieve this extension to the whole country as quickly as possible and this was contrary to the consultant's recommendation that the extension should proceed district by district with the same level of training input that had been used in the pilot district. As a result, all of the district engineers attended the training courses by the consultant (although this exceeded the agreement under the contract with the consultant) with the intention that these would be able to train the inspection teams and data processors in the remainder of the country.

The consultants specifically recommended that, before the management system could be extended country-wide, it would be necessary to appoint a full-time system manager and a full-time training officer to supervise training of new teams and retraining of existing teams. The consultant also pointed out that the system could not be introduced at zero cost and that, for the system to operate satisfactorily, new staff would be needed to undertake the condition measurement surveys and computer input. The consultants had originally offered to extend their contract to undertake the supervision of the extension to the remainder of the network. Although the donor was keen to provide the additional funding necessary for this to take place, the client decided to undertake this work itself.

The countrywide extension was carried out by the client and enquiries by the donor received the reply that everything was going well and that there were no problems. Eventually, the client applied to the same donor for a further loan, this time for pavement strengthening. The donor asked to see the computer printouts based on the field inspections from the management system to indicate why and where pavement strengthening was needed. Unfortunately, the client was not able to produce these.

3.3.4 Findings of the study

The study provided evidence that road maintenance assistance projects undertaken by consultants have often failed to introduce sustainable technology transfer and effect permanent improvements in road maintenance department's performance. Examination of projects designed to introduce a maintenance management system revealed that this type of project was also unlikely to be successful. Failure was due not to any inherent faults in the system introduced but because institutional and managerial shortcomings in the host organisation were not recognised and corrected before implementation.

Maintenance management systems require for successful operation:

1. Agreement on the aims and method of implementation between the client and consultant.
2. Sufficient, motivated staff properly supervised.
3. An integral training and retraining programme.

Whereas agreement on aims and methods can be achieved relatively easily, provision of staff, supervision and training ultimately depends on the institutional and managerial capability of the maintenance department. It is hard to see how proper staffing levels, training and incentives can be introduced to ensure the success of a maintenance management system without also attempting to correct fundamental shortcomings in a maintenance department's overall management and technical competance.

Before such systems are introduced, or any other form of assistance is contemplated, it is concluded that a thorough review of the recipient department's capabilities is undertaken. In this way, the most effective form of assistance in the circumstances currently prevailing can be identified.

Such an approach may well confront donors, recipient governments and consultants with an unpalatable dilemma. Although, in some instances, it will reveal that technical assistance, plant renewal or introduction of a management system may be appropriate, it will often be seen that a more radical approach is required. Changes in administration, accountancy, finance, contract procedures, even the law may be necessary. Identification of such problems is the first requirement. Finding an acceptable 'modus operandi' to resolve them is crucial if the current costly deterioration of developing

countries road networks is to be halted and reversed.

The current situation was summed up effectively in one of the presentations to the PTRC (1985) seminar:

"Most consultants are still on the learning curve in road maintenance management systems; so are their clients and the donor."

3.4 ASSESSMENT OF MAINTENANCE CAPABILITY

3.4.1 Methods of assessment

There are several ways of assessing the existing maintenance capacity of a roads organisation (Robinson 1984). Any competent road engineer should be able to make a subjective assessment by simply inspecting a sample of roads. Lack of effective maintenance will be shown by the level of deterioration of the road network taken as a whole. Watching maintenance gangs working in the field will also give a good indication of the likely productivity and durability of maintenance operations. However, objective assessments of maintenance capability can also be made.

Field measurements can be taken of several functions and these should be used in conjunction with available records from the road maintenance organisation to enable the assessment of capability to be made. Appropriate maintenance functions that can be included here are the availability and utilisation of specific items of maintenance equipment, the productivity achieved in certain maintenance activities and the frequency of carrying out periodic maintenance.

As has been noted earlier, poor availability of maintenance equipment is almost always a sign of an inefficient maintenance organisation. Hence measurements of availability and utilisation, particularly of key items of equipment such as graders and bitumen distributors, gives a good indication as to whether a particular organisation has the capability to carry out maintenance work efficiently. Availability is measured simply as the proportion of working days that the equipment is in a suitable condition to work. Utilisation is the actual hours that equipment is working as a proportion of the total machine hours in a given period of time. Clearly, the actual utilisation of equipment is constrained by its availability. An efficient maintenance organisation would normally expect to have average equipment utilisations of at least 50 per cent. Availabilities and utilisations for the previous year should be obtained from records, if available. Non-availability of records may in itself be a good indicator that equipment availability is low. It is vital that field checks of equipment use are made over as long a period of time as possible. The results from the field checks should be compared with the organisation's own records as this will highlight systematic errors of recording that might invalidate these records.

In a similar way, records should be collected and compared with field measurements of productivity rates for selected maintenance activities. These should be compared with the performance standards in Table 8.2 of Overseas Road Note 1 (TRRL Overseas Unit 1987). It is important that field measurements made over a reasonable length of time are used for this assessment, and that the measured productivities take account of any unproductive time, irrespective of the reasons why this arises. It is not sufficient for the appraisal to quote standard productivity rates used by the maintenance organisation as these will normally represent ideal or target values which are unlikely to be achieved in practice. The actual productivities achieved by a reasonably efficient maintenance organisation should lie within the range of outputs quoted in Table 8.2 of Overseas Road Note 1.

A third check can be made to assess the maintenance capability. On average, paved roads carrying average traffic levels should have been surface dressed every 5–8 years, and all gravel roads carrying one or two hundred vehicles per day should have been regravelled every 5-8 years. The surface dressing and regravelling achievements for the last three years should have been checked to see if, on average, between 1/8th and 1/5th of the network has been surface dressed or regravelled in each of those years, and also whether the proportion achieved each year is constant, increasing or declining.

Inspections should be made to typical lengths of paved road using the methods and criteria recommended in Overseas Road Note 1. If maintenance has been effective, very few lengths of paved road should be in need of 'special maintenance' as defined in Table 7.2 of Overseas Road Note 1. The existence of corrugated gravel and earth roads is not a good indication of maintenance capability as, even with a high level of maintenance, corrugations can appear within a few days of the maintenance having been carried out.

The capability to carry out maintenance, as estimated from the above, must be compared with the maintenance requirements for the organisation in question. Their work programme and budget allocations should be studied, and

information obtained from these should be compared with the results of field inspections in order to assess the maintenance requirement. The requirement and the assessment of capability can then be compared.

3.4.2 Considerations for capital projects

For a typical road project in a developing country, road user costs can represent up to about 80 per cent of the total road transport costs over the project life. Construction costs are of the order of 20 per cent of costs whereas maintenance costs account for only a few per cent of the total cost (Parsley and Robinson 1984). Although maintenance costs normally only account for a small fraction of the initial investment costs of the road, they are an important item in the budgets of many countries. This can lead to particular problems where investment costs are covered by foreign aid donors and maintenance must be financed locally. In addition, because maintenance can be delayed from one year to another without immediate disastrous consequences, it is tempting for hard-pressed finance ministers to economise on this item rather than on some other element of the budget. The cumulative effect of such policies is that road maintenance departments are frequently under staffed, badly trained and demoralised compared to other departments dealing with new investment. These factors often result in pressures on financiers and consultants to support projects providing higher engineering standards than are economically justified in an attempt to reduce the future maintenance burden. Such pressures should be resisted since higher standards than are necessary draw investment funds away from other priority areas and undermine the creation of proper maintenance departments which are essential in the long term (Winpenny 1984).

Inadequate maintenance can have a significant effect on the feasibility of a project. As has been noted in Section 2.1, lack of maintenance, or lack of effective maintenance, which leads to a road pot-holing can lead to a 15 per cent increase in vehicle operating costs. If this situation continues, and the road surface disintegrates, vehicle operating costs can increase by up to 50 per cent. Similarly, lack of maintenance can lead to the need for premature rehabilitation of a road with the result that the project does not provide an appropriate level of service for the anticipated life. On roads carrying high traffic levels, maintenance works impede traffic flow and may therefore reduce the value of benefits expected in the future.

Many construction and improvement project appraisals have apparently overlooked the fact that insufficient funds, personnel, equipment, materials and appropriate skills exist in the country to carry out the necessary level of maintenance on the new project, or indeed on any other road. If maintenance fails to reach the planned standard, anticipated benefits will not be achieved which, in most cases, negates the case for the project (Robinson 1984).

It is unrealistic to assume that subsequent maintenance of a new project will be carried out any better than maintenance currently carried out on the existing road network. The recommendations in project appraisals should therefore be based on the observed maintenance capability of the country itself. Unless the project includes a special component aimed at improving maintenance performance which has a realistic chance of success, the appraisal and design of a new project should be based on the assumption that it will receive the same level of maintenance as is being applied to comparable roads in the country at the time the appraisal is being carried out. Hence, the assessment of maintenance capability, as described in Section 3.4.1, should always form part of a project appraisal when capital projects are being considered.

4 MANAGEMENT ISSUES

4.1 MAINTENANCE MANAGEMENT SYSTEMS

Although there are still some technical problems to be solved in connection with road maintenance, most problems that exist are institutional or managerial in origin, rather than technical (Robinson 1986). The problem of road maintenance is principally one of getting the right personnel, materials and equipment to the right section of road to carry out the right remedial or preventative work at the right time.

Modern management systems (PTRC 1985, 1986) have been introduced in some countries to try to improve the organisation of maintenance. Unfortunately, the implementation of systems such as these into developing countries has often proved ineffective as was indicated in Section 3.3. The study carried out by TRRL showed that management systems can be useful tools but, if introduced, their purpose and the benefits from their use must be fully understood by the people expected to operate them. The systems must be appropriate to the country where they are being used and not just 'borrowed' from other countries where maintenance

problems and social conditions may be quite different. Systems cannot be introduced at zero cost or without additional staff. They should be simple and easy to use.

When introducing a system, a progressive approach should be adopted, with development over several years. This will ensure that initial efforts can be concentrated on tasks which will produce early and tangible results. Only when one stage has been set up and is working reasonably well should the next stage be attempted. Within a country, it may be best to introduce new procedures on a district-by-district basis as this enables training resources to be utilised more easily. Initially, efforts should be concentrated on the most heavily trafficked lengths of road. When maintenance on these is satisfactory, maintenance planning should be extended to the less heavily-trafficked roads.

Implementation of systems into several countries has been unsuccessful because of failure to recognise the need for and to implement the above items.

4.2 OBJECTIVES OF PAVEMENT MANAGEMENT SYSTEMS

A pavement management system has several purposes. Among these will be the following: (Robinson and Snaith 1985).

(i) To provide the means of developing annual work programmes, resource requirements and budgets.
(ii) To ensure an equitable distribution of funds over the country and to enable priorities for allocations to be determined in a rational way when available funds are inadequate.
(iii) To authorise and schedule work.
(iv) To provide a system of monitoring the efficiency and effectiveness of maintenance works.

The work programmes, resource requirements and budgets identified will depend on the types of maintenance procedures used, the frequency with which these are carried out, and the size of the management and organisational overhead needed to support the maintenance activity. The system will also provide factual data to support budget requests when these are made to senior roads organisation staff or to Ministries of Finance. These data will be obtained as a result of determining maintenance needs using quantitative field inspections and monitoring work completed to ensure that it has been carried out in a cost-effective manner. The equitable distribution of budget over the whole country should recognise that needs and costs will be different from region to region depending on geographical location, climate, topography, soils and the particular nature of the network within the region. Recommended priorities for work in the event of a shortfall in budget will depend on the importance of the region in which the road is located, the political or strategic importance of the road in question, the traffic and axle loading, the type of road surface and the effect on the rate of road deterioration which would be caused by the work being deferred. This latter item will also depend on the climate, topography and soil type in the area in which the road is located.

A pavement management system achieves these objectives by providing a systematic method of operation for all staff engaged on maintenance work. Thus a management system is principally concerned with managing the people who have the responsibility for managing the road network.

4.3 STEPS IN THE MANAGEMENT PROCESS

A pavement maintenance management system normally contains the following components (Robinson 1986):

(i) *Inventory:* This is used as the basic reference for planning and carrying out maintenance and inspections.
(ii) *Inspection:* Road condition should be determined by taking physical measurements of defects on the road network in the field.
(iii) *Maintenance needs:* These are determined by comparing the measurements of road condition with predetermined maintenance intervention levels that are based upon economic criteria.
(iv) *Costing:* Unit costs are applied to the identified maintenance tasks to determine the budget required.
(v) *Priorities:* If the budget is insufficient for all of the identified work to be carried out, it is then necessary to determine priorities to decide which work should be undertaken and which should be deferred.
(vi) *Execution:* The work identified should be carried out, and several systems of scheduling and cost-accounting are available to assist with this.
(vii) *Monitoring:* This serves two purposes:
  (a) it ensures that work identified has, in fact, been carried out,

(b) it provides data to enable unit cost and intervention levels to be checked and adjusted if necessary.

These basic steps form the basis of managing the road network in a maintenance district which is the subject of Overseas Road Note 1 (TRRL Overseas Unit 1987).

4.4 ECONOMIC BASIS FOR MANAGEMENT

It is recommended that the appropriate level of maintenance should be determined in terms of the whole life costing of the road (Robinson and Snaith 1985). An attempt should be made to minimise the sum of maintenance cost, upgrading or reconstruction cost, and road user cost over the road's life by choosing the optimum level of maintenance. If roads are maintained too soon, then the full value of the existing pavement will not be obtained and maintenance costs will be too high. If roads are maintained too late, the maintenance needed will be much more expensive. Thus, maintenance intervention levels should be chosen such that the resulting level of maintenance is optimum from an economic standpoint. For roads in developing countries, intervention levels should be determined, wherever possible using economic models (Parsley and Robinson 1982, Watanatada *et al.* 1985).

For paved roads, maintenance should normally be carried out in response to the appearance of defects and it is necessary to set intervention levels such that certain severity levels of defects trigger the application of defined maintenance measures. These intervention levels should be chosen such that the resulting level of maintenance is the economic optimum. Thus, for paved roads, inspections should be carried out once or twice a year to determine the maintenance needs for the following maintenance and budgetting period. The deterioration patterns of unpaved roads are very rapid when compred with those constructed with a bituminous surface or with concrete. A gravel road carrying several hundred vehicles per day will need to be graded several times a year. It is therefore unrealistic to carry out such a maintenance operation in response to defect levels measured during road inspections. A different approach to maintenance management for unpaved roads is therefore needed. In this case, intervention levels should be chosen using economic criteria and maintenance should be programmed in advance so that it is carried out at the appropriate time. Thus, the maintenance of paved roads should be carried out on a responsive basis whereas the maintenance of unpaved roads should be programmed.

4.5 MAINTENANCE MANAGEMENT OF UNPAVED ROADS

4.5.1 Maintenance operations

Many maintenance organisations in developing countries find it difficult to carry out anything other than minimal work to their unpaved road networks. There is a need to plan maintenance in an optimal way, but it is recognised that the introduction of any systematic management of maintenance, even if sub-optimal, will be an improvement over the existing situation.

A methodology for planning maintenance of unpaved roads in developing countries has been developed by TRRL and is described in Research Report 91 (Jones and Robinson 1986).

The principal operation in maintaining earth and gravel roads (TRRL Overseas Unit 1985) is grading which can be carried out either with a motor grader or towed grader. In addition, dragging may be carried out with the objective of controlling corrugations, and light or routine grading is also carried out for this reason. Heavy grading is used to reshape the road surface and to restore it to its correct camber or crossfall and to provide a smooth running surface. This activity normally includes watering and compaction. Heavy grading can be combined with regravelling to restore the thickness of the gravel surface. Filling or patching of local deformation are labour-intensive operations to deal with the worst defects on low-volume roads for which the expense of grading or other machine activities cannot be justified.

4.5.2 Grading

An appropriate frequency of grading needs to be determined for each individual road. The frequency needed will depend on the surface material type and gradation, traffic, climate, topography and other physical features, and should be chosen to keep the road in as near to the optimum economic condition as possible. Initial frequencies of grading should be determined by carrying out economic studies using a road investment model such as those developed by the World Bank (Watanatada *et al.* 1985) and the TRRL (Parsley and Robinson 1982).

The appropriate level of maintenance should be determined in terms of the whole-life costing of the road. The investment model can be used to search for that frequency of maintenance that

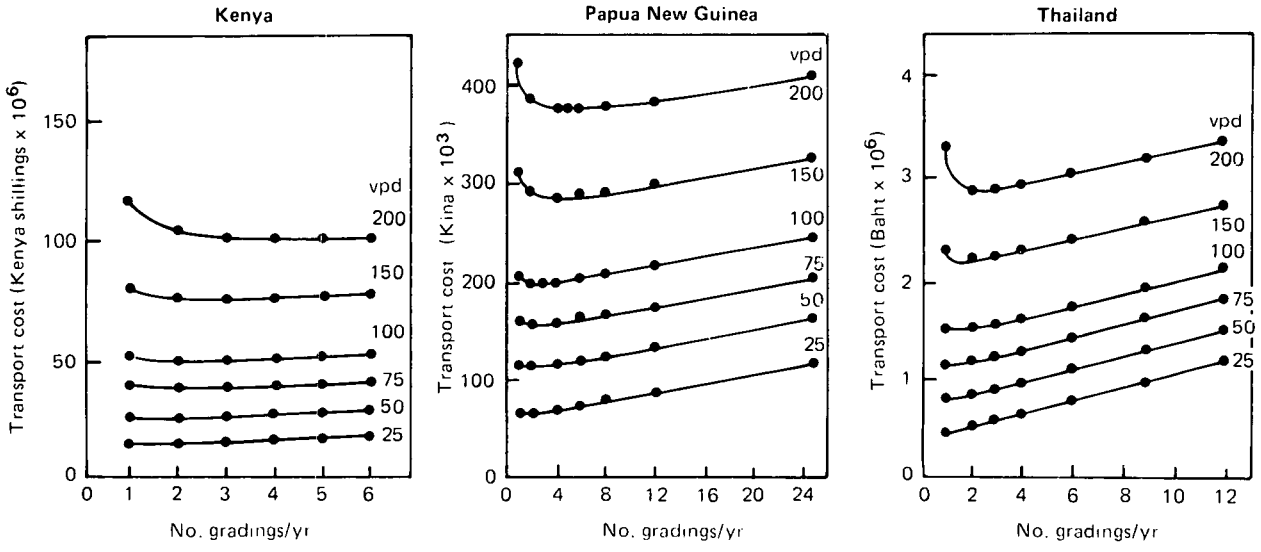

Fig. 1. The dependence of transport cost on grading frequency for Kenya, Papua New Guinea and Thailand

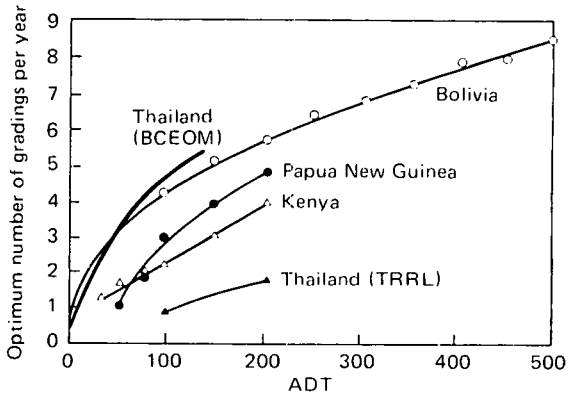

Fig. 2. Optimum grading frequency curves for Kenya, Papua New Guinea and Thailand compared with those for Bolivia

minimises the sum of maintenance cost and road user cost over the road's life. The optimum value of maintenance derived will be different for roads in different areas and for roads carrying different levels of traffic or built with different materials.

Figure 1 shows plots of whole life road cost against grading frequency and traffic level derived by TRRL for particular roads in Kenya, Papua New Guinea and Thailand. For the higher traffic levels, distinct minima of total cost can be seen, indicating the optimum grading frequency. Note that these optimum frequencies are quite different for each of the countries studied, and are different again from those found by other workers in Bolivia (Butler *et al.* 1985) and Thailand (BCEOM *et al.* 1981) (Figure 2). This emphasises the need to carry out detailed investigations, not only for each country and traffic level, but also for each surfacing material type.

Once the recommended optimum grading frequencies have been implemented in the field, a monitoring system should then be established and this can be linked to a proprietary maintenance management system (Snaith *et al.* 1982, 1985). A representative sample of unpaved roads should then be monitored for a period of at least one year and measurements taken of riding quality (roughness) and rut depth immediately before and after each maintenance grading carried out at the prescribed frequency. Traffic levels on these roads should also be monitored.

Modifications to the grading frequencies can then be made to ensure that the mean values of roughness and rut depth are such that the sum of road maintenance and road user cost is minimised. In this way, by the end of the year, grading frequencies will have been obtained that are calibrated for local conditions in such a way that they are close to optimum. A sample of the road network should have its performance monitored on a continuing basis to ensure that the grading frequencies being used are still keeping the roads in a condition that is close to the optimum. Any adjustments can then be made to the grading frequencies that prove necessary.

4.5.3 Roughness

Measurements of roughness will normally be measured with a 'response-type' instrument and it will be necessary to calibrate this to ensure that the results obtained are consistent with the 'm/km' values used for vehicle operating cost calculations in the road investment models. Equations now exist (Sayers *et al.* 1986) for relating standard roughness values to the absolute longitudinal profile of the road. The response-type instruments used can be calibrated

by running them over roads with various degrees of roughness. The longitudinal profile can be determined by measuring the road with a rod and engineer's level. However, this method is laborious and the calculations needed to determine the calibrated values are time consuming. An instrument has been developed at TRRL for calibrating response-type roughness measuring devices more easily and this is known as the 'Abay beam' (Abaynayaka 1984). This contains a microprocessor and, when the machine is used on the road, an automatic readout of calibration roughness is obtained.

Many maintenance engineers working in developing countries will not have access to the computer methods and roughness measuring equipment that are necessary to determine optimum grading frequencies in the way that has been recommended above. In such cases, grading frequencies can be determined by drawing a mean line through the various curves in Figure 2. A simple grading frequency chart for different traffic levels is provided in Overseas Road Note 1 (TRRL Overseas Unit 1987) and the derivation of this is described in Research Report 91 (Jones and Robinson 1986).

4.5.4 Dragging

Dragging should be used in areas where either loose material lies on the road or where materials tend to corrugate. Particularly in areas where corrugations tend to form, the frequency of dragging necessary is likely to be of the order of a few days. The present generation of road investment models are not calibrated for roads that corrugate, so the frequency of dragging cannot be determined using economic criteria. The actual frequency must be determined by carrying out simple experiments of the dragging requirement needed to stop the formation of corrugations. This frequency will vary for different material types, traffic levels and in difficult areas. As for grading frequencies, the effectiveness of the adopted maintenance frequencies must be monitored over time to ensure that the roads are still being kept in an appropriate condition. Dragging frequencies should be modified if that proves necessary.

4.5.5 Regravelling

The management of regravelling should be carried out on a 'responsive' basis and timed to replenish material when its thickness has been reduced to a level that no longer provides sufficient structural strength to support the traffic using the road (Robinson 1986). However, it is not sufficient to wait until the material has worn away before acting since, because regravelling is a relatively high cost activity, information is needed to enable the timing of the work to be planned in advance.

Records of when each road was regravelled and the thickness and type of materials used should be kept. However, TRRL's experience of regravelling records is that they do not always give a true guide to the material's quality or of the layer thickness. It is therefore recommended that information in these records is supplemented by a limited number of test pits and testing after regravelling.

TRRL gravel loss equations can then be used to predict when the gravel thickness will be reduced to the minimum necessary for structural support and to enable regravelling plans to be made for the future. TRRL's more recent work in Kenya (Jones 1984b), Ethiopia (Beaven *et al.* 1987, Newill *et al.* 1987) and Botswana (Toole *et al.* 1987) suggests that the original equations underestimate the actual losses likely to be obtained. It is recommended that the loss rates predicted by the original equations should now be increased by about 35 per cent. The following predictive equation is now recommended (Jones 1984b):

$$G_L = F\left[\frac{T_A^2}{T_A^2 + 50}\right](4.2 + 0.092T_A + 3.5R_L^2 + 1.88V_c)$$

where G_L = gravel loss in mm
F = factor depending on gravel type
= 2.06 for coral gravels
= 1.29 for lateritic gravels
= 1.51 for quartzitic gravels
= 1.38 for sandstone gravels
= 0.96 for volcanic gravels
T_A = total two-way traffic in thousands of vehicles
R_L = annual rainfall in metres
V_c = mean percentage gradient

An example of prediction curves for lateritic gravel is given in Figure 3. This relationship can be used to plan future regravelling requirements and to prepare long-term budgets. However, the relationships should be calibrated for local conditions by monitoring actual gravel thicknesses over time to determine actual rates of loss. This information can be used to make modifications for the future. Ideally, thicknesses should be measured immediately after grading by digging small holes in the road to determine whether regravelling is necessary. However, in view of the difficulty of timing such measurements and the need to carry out measurements on a routine basis, the following approach may be more appropriate. The survey crew should identify any obvious ruts and should dig two holes: one in the rut and one midway between ruts. The gravel thickness should be calculated

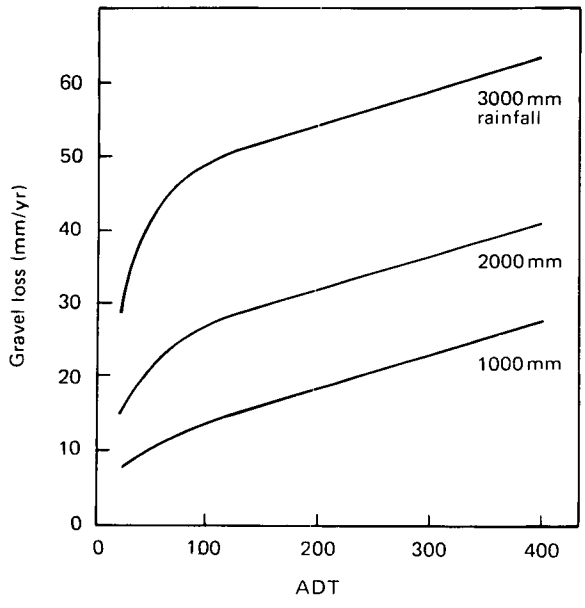

Fig. 3. Gravel loss prediction curves for Laterite

as the average of the two recorded measurements (TRRL Overseas Unit 1987). Traffic levels will also need to be monitored. In this way, the monitoring system should, in time, provide information about the expected lives of the different types of materials used for the gravel surfacings under different conditions of traffic and other parameters appropriate to local conditions. This will enable plans for future regravelling to be made with much greater certainty.

4.6 INSPECTION AND INTERVENTION LEVELS FOR PAVED ROADS

4.6.1 Assessment of maintenance needs

In order to assess maintenance needs in the various parts of a country, it is necessary to carry out a condition measurement survey of the entire road network with the purpose of identifying work that needs to be done (Robinson 1986). For the purposes of routine, recurrent and periodic maintenance, this requires that inspectors walk all of the roads and carry out simple measurements of road condition. Methods of carrying out such surveys are described in Overseas Road Note 1 (TRRL Overseas Unit 1987). The condition measurements obtained in this way can then be compared with economically-based intervention levels to determine maintenance needs. However, for paved roads, the relationship between the rate of pavement deterioration and the level of maintenance is very sensitive to complex variations in the parameters of traffic loading, climate, pavement materials, etc., and these relationships have still to be quantified adequately. Until such time as the research evidence can provide robust relationships that can be used to predict optimum maintenance levels for paved roads, intervention levels such as those given in Overseas Road Note 1 must be used.

Providing that the same intervention levels are adopted country-wide, the maintenance requirement identified in this way will be objective, and funds allocated on the basis of the requirement identified will be equitable between the various regions. In this way, the results of condition assessments can and should be used as the basis for both budget requests and the allocation of funds. As the funding requests will be based on rational criteria that are consistent throughout the country, it is not only possible to allocate funds in a more equitable way, but it is also possible to demonstrate to politicians and to senior finance ministry officials the basis on which budget allocations have been made. In addition, the consequences of a shortfall in allocation can also be demonstrated in terms of the effect on the country's economy in general. If it is not possible to provide funds to carry out all the maintenance works identified, then it is possible to use the data that have been collected to make rational and objective decisions about which maintenance activities can be deferred so as to be least damaging to the country's economy as a whole in the long term.

4.6.2 Rapid methods of assessment

The assessment of maintenance needs in the way that has been described satisfies all the basic requirements of objectivity and rationality that are needed. The effect of parameters such as soils, topography and climate will also be taken into account through the effect that they will have on road condition.

However, the introduction of such a system of assessment can prove difficult and it can take a long time to implement. It will be necessary to develop optimum intervention levels for the country in question, to produce an inventory of the network to provide the basis for the inspections, to train and equip staff to carry out the inspections and to introduce a system for recording and analysing the data collected. Although the introduction of such a system should be a target for all countries, it will probably be necessary to adopt an interim method which can be used whilst the final system is being introduced.

As an interim measure, it is probably only possible to rank roads according to their condition and to carry out physical condition

surveys at a sample of points to enable the required maintenance works to be determined.

Deflections

On major roads in Britain and several other industrialised countries, the method of rapid ranking most commonly used is that of deflection measurements (Kennedy 1978). These measurements are used in conjunction with deflection criteria curves (PIARC 1979a) and information on the cumulative standard axle loading carried by the road to determine orders of priority for works. It is possible to make rapid measurements by using equipment such as the deflectograph, falling weight deflectometer, etc. (Snaith 1985). However, such rankings only give a guide to the structural condition of the road and to the strengthening requirements. They do not provide any guidance on the maintenance requirements in terms of the needs for recurrent and periodic works. Indeed, the experimental evidence at the moment suggests that, for roads with thin bituminous layers in the tropics, the use of deflection measurements combined with a knowledge of cumulative standard axle loading is even insufficient to enable predictions about future strengthening requirements to be made (Smith *et al.* 1980). Deflection methods are also inappropriate for use on unpaved roads.

Visual assessment

The method most commonly used for condition assessment in developing countries is for an 'experienced engineer' or team of engineers to carry out a subjective visual assessment, sometimes by driving over the roads in a vehicle (Brett and Kerridge 1978, Van der Merwe 1979, Skok and Kersten 1978, Skok and Lukanen 1979, PIARC 1979b). Typically, roads are rated on a scale of 0–5 in terms of their 'serviceability'. The level of serviceability then determines the priority ranking for repair and upgrading works. In some cases, the results of visual assessments are combined with measurements such as deflections using statistical relationships which are also usually based on subjective appraisal (Gordon and Curtayne 1979, Gordon and Papendorf 1979, Rananand 1978). It is very difficult to justify such an approach, particularly when it is not related in any scientific or rational way to the engineering requirements or the economics of repair or upgrading. This approach is particularly dubious when consulting engineers with experience in one country are brought in to carry out an assessment of the road network in another country. Average road conditions vary tremendously from country to country and a level of serviceability which is 'unacceptable' in one may be quite normal in another. In view of the importance of such surveys and the relatively large costs which depend upon their outcome, it is reasonable to suggest that a more objective and repeatable method of measurement should be used.

Roughness measurement

Although it has some limitations, probably the best method currently available for carrying out road ranking surveys is by measuring riding quality (roughness). There are two principal reasons for this.

At the time of the AASHO Road Test (Liddle 1962), several surveys and analyses were carried out to devise a parameter for summarising the overall condition of any stretch of road. The concept of Present Serviceability Index (PSI) was developed and the PSI parameter was used to rank roads on a scale of one to five. Statistical analysis showed that PSI was related to the parameters of slope variance (roughness), rutting and the amount of cracking and patching on the road. However, it was noted that around ninety per cent of the variability in the value of PSI was accounted for by the variability in the value of roughness. Hence, the roughness measurement is clearly the best single indicator of condition when considered from an engineering point of view.

As discussed earlier, considerations of road economics are influenced greatly by considerations of road user costs. Studies of road user costs in developing countries that have been carried out by TRRL (Abaynayaka *et al.* 1977, Hide 1982), the Indian (CRRI 1982) and Brazilian governments (Harrison and Chesher 1983) and the World Bank, have all shown conclusively that the main parameter that links road condition with vehicle operating costs is that of roughness. Thus roughness is the principal parameter that should

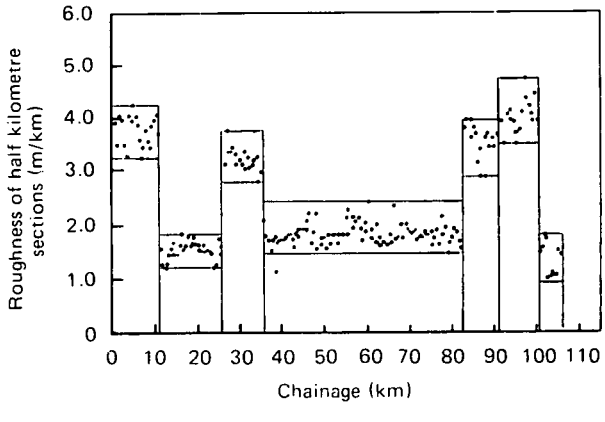

Fig. 4. Results of typical roughness survey

be measured when determining the economic effect of road maintenance.

The results from a typical survey of road roughness are illustrated in Figure 4. It can be seen here how the measurement of roughness clearly sub-divides the road into lengths with relatively homogeneous surface conditions. Those sections of road in more urgent need of maintenance are clearly identified. Vehicle-mounted roughness measuring equipment is relatively cheap and easy to install and, providing that results are only being used for road ranking and not for the purpose of calculating absolute vehicle operating cost values, sophisticated calibration procedures are not required. TRRL recommend (Abaynayaka 1984) that roughness surveys are carried out at 32 km/h, so it is normally possible to survey upwards of 150 km of road in one day.

It is important when carrying out roughness surveys for road ranking purposes, that an observer in the vehicle makes notes about the type and general condition of the road surface, and the condition of shoulders and side drains referenced to the roughness readings. This greatly assists the subsequent interpretation of the roughness results. It is also important that proper condition surveys, as described earlier, are also carried out on a sample of the road network as this again enables the maintenance implications of the roughness survey to be interpreted with more certainty. In this way, rapid ranking surveys based on roughness measurements can be used as the basis for distributing available maintenance funds in a reasonably objective and equitable way over the country as a whole. However, this method should only be used on an interim basis.

4.6.3 Criteria for repair

Road condition measurement surveys for determining maintenance needs should use the road inventory as their basic reference point, but inspections should also be related to maintenance intervention levels. These will establish when and where repairs are needed and will identify which maintenance techniques should be used in response to different defects.

The activities of recurrent and periodic maintenance are interactive as the application of periodic surface dressing will defer the need for recurrent maintenance. Carrying out recurrent maintenance will not affect the need for periodic work although, if recurrent work is neglected, this will eventually result in the need for rehabilitation. In an optimum maintenance situation, recurrent maintenance will only be needed at local areas of weakness, as resealing the pavement will inhibit surface deterioration. Depending on the type of recurrent work and how well it is carried out, it can either increase or decrease the riding quality (roughness) of the road. The immediate effect of this may be significant, but the longer term effect on the rate of increase of roughness is likely to be small. Hence, recurrent maintenance is only likely to have a small effect on the long-term increase or reduction in road user costs. The main effect on both road user cost and pavement life will be as a result of surface dressing or overlaying.

It has already been mentioned that, at the moment, it is difficult to base maintenance intervention levels for paved roads on economic criteria. Until such time as this is possible, it is suggested that maintenance needs are based on intervention levels such as those in Overseas Road Note 1 (TRRL Overseas Unit 1987). It should be the ultimate goal of all countries to develop their own maintenance criteria based on their particular economic and physical conditions.

Using the intervention levels in Overseas Road Note 1, it will be seen that, in some cases, where deterioration is critical or advanced, there is a need for 'further investigation' to determine what action is appropriate. Roads in such condition are beyond the point where normal maintenance is sufficient to ensure the serviceability of the pavement, and special measures will be needed. It will be necessary to use measurements such as roughness, dynamic cone penetration, deflection, etc. (Snaith 1985), to determine whether strengthening or rehabilitation is needed and to design appropriate remedial measures. As discussed in Section 1.2, such works are not normally classed as maintenance and, as such, are beyond the scope of this Report.

5 SUMMARY: THE WAY AHEAD

5.1 REVIEW

This Report has reviewed road maintenance in developing countries in terms of economics and policy, project implementation, and management. It should be read in conjunction with Overseas Road Notes 1 and 2 (TRRL Overseas Unit 1987, 1985).

There are several areas where steps need to be taken to help to ease the road maintenance problem in developing countries.

5.2 NETWORK PRIORITIES

Of the roads budgets available in developing countries, very little is normally allocated to

maintenance. Governments should, therefore, reduce the amount of new construction and improvement they undertake and use the funds saved to increase the amount of preventative and periodic maintenance. Any funds available after this changeover should be used for reconstruction of pavements that have failed due to lack of maintenance.

Only after all of the above are done, should funds be spent on new construction and improvements. In some countries, the reallocation of funds from new investment to maintenance would be sufficient to put the road network back into good condition. In others, however, reduction in the size of the road network is necessary if the country is to become self-supporting in the maintenance of its road system.

To abandon parts of the road network is politically very difficult for governments to acknowledge and implement. However, a number of countries have developed a road system which is more than they can afford with their own resources at present levels of efficiency, and the network may, in any case, be more than is necessary for present traffic needs. Where a country cannot maintain its road system from its own resources and foreign aid on a continuing basis is not available for maintenance, either parts of the system must be abandoned or continuing deterioration throughout the whole network is inevitable.

The problem of pavement damage is exacerbated by the damage being done by overload vehicles. In most developing countries, overloading is rife and its control would generate large road maintenance savings. There is more scope for the control of imported vehicle dimensions. Many developing countries allow vehicles to be imported or assembled that are illegal on the roads of Europe and North America because of an insufficient number of axles to spread the potential loads that can be carried.

5.3 FINANCE

It is essential that countries provide adequate finance for maintenance and to support this with an appropriate commitment of foreign exchange resources. In addition to the transfer of funds from other parts of the road subsector, there is scope for better cost-recovery through taxation to increase funding. In many countries, road haulage is subsidised by other sectors because of a failure to apply equitable taxation. In other countries, revenue earned through taxation of the road sector is spent elsewhere in the economy. Although, the disbursement of revenues is a political issue, consideration should be given to the use of earmarked taxes or road funds in those countries where road maintenance expenditure is inadequate or funds uncertain or irregular.

5.4 EFFICIENCY

For maintenance operations to increase in efficiency, there is a need to strengthen management at all levels and to provide management training. Despite many years of technical assistance projects, there are shortages of skilled personnel in most countries. Training requirements are often underestimated and the need for retraining on a long-term continuous basis is often not appreciated. Although the need for staff training should be emphasised, any benefits will only be realised if trained staff are adequately reimbursed and provided with incentives to perform well. There is scope for the restructuring of posts to make maintenance staff more senior and thus to provide the incentive for attracting the more able staff. The payment of productivity bonuses could be introduced in the same way as is common on new construction projects.

The use of private sector maintenance contractors has much to offer in terms of increasing efficiency, particularly for periodic maintenance, and roads departments should be encouraged to experiment with their use. A further option is for the ministry's works department to operate as a contractor for work placed by the maintenance department. This system has been introduced successfully into the UK. There is also considerable potential use for labour-intensive methods that will have a much lower requirement for foreign exchange, but have much greater need for management skills. In particular, 'lengthsmen' could be used to be responsible for the routine maintenance of fixed lengths of road and whose payment would depend on results.

The lack of working equipment is almost always a factor in maintenance organisations that are inefficient and there is considerable scope for improving the management of this expensive resource. The use of commercially-based hire charge systems is likely to inculcate greater cost-consciousness and efficiency. By making the financing of plant hire organisations dependent on the revenues generated, there will be strong incentives to keep plant serviceable, since broken-down items produce no revenue.

In general, there is a much greater need for individual responsibility and cost-accountability at all levels, and it is important that a lead is given at the highest political level. Priorities for funding must be assigned, coupled with a determination to carry policies through without a diversion of resources to other peripheral activities. There is an increasing awareness of the road maintenance problem in many developing

countries. What is needed now is a concerted effort by the countries themselves supported by coordinated and appropriate actions by bilateral and multilateral aid donors to build up institutions and to develop road maintenance capability.

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It has already been mentioned that, at the moment, it is difficult to base maintenance intervention levels for paved roads on economic criteria. Until such time as this is possible, it is suggested that maintenance needs are based on intervention levels such as those in Overseas Road Note 1 (TRRL Overseas Unit 1987). It should be the ultimate goal of all countries to develop their own maintenance criteria based on their particular economic and physical conditions.

Using the intervention levels in Overseas Road Note 1, it will be seen that, in some cases, where deterioration is critical or advanced, there is a need for 'further investigation' to determine what action is appropriate. Roads in such condition are beyond the point where normal maintenance is sufficient to ensure the serviceability of the pavement, and special measures will be needed. It will be necessary to use measurements such as roughness, dynamic cone penetration, deflection, etc. (Snaith 1985), to determine whether strengthening or rehabilitation is needed and to design appropriate remedial measures. As discussed in Section 1.2, such works are not normally classed as maintenance and, as such, are beyond the scope of this Report.

5 SUMMARY: THE WAY AHEAD

5.1 REVIEW

This Report has reviewed road maintenance in developing countries in terms of economics and policy, project implementation, and management. It should be read in conjunction with Overseas Road Notes 1 and 2 (TRRL Overseas Unit 1987, 1985).

There are several areas where steps need to be taken to help to ease the road maintenance problem in developing countries.

5.2 NETWORK PRIORITIES

Of the roads budgets available in developing countries, very little is normally allocated to

maintenance. Governments should, therefore, reduce the amount of new construction and improvement they undertake and use the funds saved to increase the amount of preventative and periodic maintenance. Any funds available after this changeover should be used for reconstruction of pavements that have failed due to lack of maintenance.

Only after all of the above are done, should funds be spent on new construction and improvements. In some countries, the reallocation of funds from new investment to maintenance would be sufficient to put the road network back into good condition. In others, however, reduction in the size of the road network is necessary if the country is to become self-supporting in the maintenance of its road system.

To abandon parts of the road network is politically very difficult for governments to acknowledge and implement. However, a number of countries have developed a road system which is more than they can afford with their own resources at present levels of efficiency, and the network may, in any case, be more than is necessary for present traffic needs. Where a country cannot maintain its road system from its own resources and foreign aid on a continuing basis is not available for maintenance, either parts of the system must be abandoned or continuing deterioration throughout the whole network is inevitable.

The problem of pavement damage is exacerbated by the damage being done by overload vehicles. In most developing countries, overloading is rife and its control would generate large road maintenance savings. There is more scope for the control of imported vehicle dimensions. Many developing countries allow vehicles to be imported or assembled that are illegal on the roads of Europe and North America because of an insufficient number of axles to spread the potential loads that can be carried.

5.3 FINANCE

It is essential that countries provide adequate finance for maintenance and to support this with an appropriate commitment of foreign exchange resources. In addition to the transfer of funds from other parts of the road subsector, there is scope for better cost-recovery through taxation to increase funding. In many countries, road haulage is subsidised by other sectors because of a failure to apply equitable taxation. In other countries, revenue earned through taxation of the road sector is spent elsewhere in the economy. Although, the disbursement of revenues is a political issue, consideration should be given to the use of earmarked taxes or road funds in those countries where road maintenance expenditure is inadequate or funds uncertain or irregular.

5.4 EFFICIENCY

For maintenance operations to increase in efficiency, there is a need to strengthen management at all levels and to provide management training. Despite many years of technical assistance projects, there are shortages of skilled personnel in most countries. Training requirements are often underestimated and the need for retraining on a long-term continuous basis is often not appreciated. Although the need for staff training should be emphasised, any benefits will only be realised if trained staff are adequately reimbursed and provided with incentives to perform well. There is scope for the restructuring of posts to make maintenance staff more senior and thus to provide the incentive for attracting the more able staff. The payment of productivity bonuses could be introduced in the same way as is common on new construction projects.

The use of private sector maintenance contractors has much to offer in terms of increasing efficiency, particularly for periodic maintenance, and roads departments should be encouraged to experiment with their use. A further option is for the ministry's works department to operate as a contractor for work placed by the maintenance department. This system has been introduced successfully into the UK. There is also considerable potential use for labour-intensive methods that will have a much lower requirement for foreign exchange, but have much greater need for management skills. In particular, 'lengthsmen' could be used to be responsible for the routine maintenance of fixed lengths of road and whose payment would depend on results.

The lack of working equipment is almost always a factor in maintenance organisations that are inefficient and there is considerable scope for improving the management of this expensive resource. The use of commercially-based hire charge systems is likely to inculcate greater cost-consciousness and efficiency. By making the financing of plant hire organisations dependent on the revenues generated, there will be strong incentives to keep plant serviceable, since broken-down items produce no revenue.

In general, there is a much greater need for individual responsibility and cost-accountability at all levels, and it is important that a lead is given at the highest political level. Priorities for funding must be assigned, coupled with a determination to carry policies through without a diversion of resources to other peripheral activities. There is an increasing awareness of the road maintenance problem in many developing

countries. What is needed now is a concerted effort by the countries themselves supported by coordinated and appropriate actions by bilateral and multilateral aid donors to build up institutions and to develop road maintenance capability.

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