Need to Set Priorities for Road Maintenance in Developing Countries

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Maintenance of a nation's roads has three main purposes. First, since the rate of deterioration is reduced, the need for very costly reconstruction will be postponed. Second, vehicle operating costs are reduced by keeping the running surface in good condition and in particular by reducing its unevenness. Third, since maintenance helps to keep roads open, the high costs of transport unreliability and delays that would result from road failures can be avoided. The total savings that result from effective maintenance can be many times greater than the cost of carrying out that maintenance. However, in many developing countries the majority of roads receive little or no maintenance. It is often claimed that insufficient resources are allocated to road maintenance, yet that maintenance which is carried out is usually executed very inefficiently. This inefficiency stems from two main constraints: a shortage of skilled, experienced personnel and an overdependence on imported resources. The consequences of these constraints are examined. The scope for achieving greater efficiency in maintenance by using labor-based methods is discussed. However, it is concluded that there will be a substantial maintenance deficit for many years to come. It is important to recognize the effective capacity for carrying out maintenance. This provides a basis for setting priorities and for meeting them at both the national and the local levels.

Maintenance of roads has three main purposes (1). First, it reduces the rate of deterioration and prolongs the life of roads. Second, it reduces vehicle operating costs by providing good running surfaces, and, third, it helps to keep roads open more continuously, particularly in the wet season. The need to prolong the life of the road is mainly in the interests of the organization responsible for road maintenance. The lowering of vehicle operating costs is mainly in the interests of road transport operators. Keeping the road open on a more continuous basis is in the interests of the traveling public at large and of industry and agriculture.

REDUCING ROAD DETERIORATION

Even with proper maintenance, roads deteriorate with time. The rate of this deterioration will depend on the climate, the type and strength of the pavement, the strength of the underlying soil, the volume of traffic using the road, and the axle load of the vehicles.

The effect of axle loading and in particular of overloaded vahicles 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 load of 8 tonnes. More significantly, an axle load of 16 tonnes does 20 times as much damage as an 8-tonne axle (2). It is clearly necessary for road maintenance purposes to know the value of the actual axle loading on a road, because minor underestimates can considerably shorten the expected life of a road and increase the maintenance inputs required.

From a road maintenance point of view, there is considerable advantage in having appropriate axle-load legislation that 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 organization is to know the magnitude of the axle loads actually being carried by roads in order that maintenance can be planned realistically.

Considerations of vehicle operating cost should dictate what road surface condition is acceptable and economical and therefore what level of maintenance is appropriate. If costs to vehicle operators are not taken into account, then no matter how bad the road surface becomes, vehicle operators would find it acceptable, provided their vehicles were not actually prevented from reaching their destination. This is clearly unrealistic.

Vehicle operating costs depend on the type of vehicle, the geometry of the road, and the condition of the surface of the road. For example, the larger the vehicle, the bigger will be its engine and the higher will be its operating cost; the steeper the gradient of the road, the more fuel will be used and the higher will be the vehicle operating cost; the rougher the road, the more the vehicle will be shaken about, which results in the use of more fuel and the more frequent replacement of tires and other parts. Over recent years, the U.K. Transport and Road Research Laboratory (TRRL), in collaboration with the World Bank, has carried out studies to quantify the way that vehicle operating costs depend on road condition (3,4) and how road condition depends on the amount of road maintenance (5), among other factors. These studies have enabled conclusions to be drawn about the way that road maintenance affects vehicle operating costs.

The best measure of road surface condition in terms of the way that it affects vehicle operating costs is that of surface irregularity or roughness. This can be measured with a range of instruments, including the bump integrator (4), which has been used in the TRRL studies. Roughness values (RVs) are obtained in millimeters per kilometer and typical values are given below:

Condition	RV (mm/km)
Paved road	
Good	2 500
Start of potholing	4 000
Badly broken	10 000
Unpaved road	
Good	5 000
Potholed	10 000
Corrugated	15 000

For all roads, there will eventually come a time when they reach the end of their design life and need strengthening or improving. Strengthening, rehabilitation, and reconstruction are all high-cost activities and postponing them can result in substantial economies. June 1980 examples of average costs for maintenance and rehabilitation activities are given (in U.S. dollars per kilometer) in Table 1 (1).

For a five-year period from the life of a typical paved road, if proper routine and recurrent maintenance are carried out, it may cost on average $500/km each year. After five years, there will probably be a need to reseal the surface of the road at an approximate cost of $9000/km. This results in a total undiscounted cost to the maintenance authority of $11 500/km for a five-year period. This same five-year maintenance cycle can then be repeated several times during the life of the road.

However, if proper routine and recurrent maintenance are not carried out, drains will not be cleared and surface defects will not be repaired. The maintenance authority may well save itself $500/km each year, but after five years, instead of resealing at a cost of $9000/km, the road will need major surfacing repairs at a cost of approximately $60 000/km to restore it to the same condition as if proper maintenance had been carried out.

Thus, for a maintenance expenditure of $11 500/km, a saving of nearly $50 000/km could result from deferred rehabilitation costs. This has a benefit/cost ratio of 4:1, and the implication is that by carrying out effective routine and recurrent maintenance on a regular basis, five times the length of road can be maintained for the same price as that by adopting a deferred maintenance policy. The costs of failing to carry out effective routine maintenance are likely to be even greater under conditions of very high rainfall or very heavy traffic.

Table 1. Maintenance and rehabilitation costs.

Road Type	Activity	Cost Range ($/km)
Earth	Routine maintenance	100-1000
Gravel and paved	Routine maintenance	200-1000
Gravel and paved	Periodic maintenance	8000-10 000
Gravel and paved	Routine and periodic maintenance (annual average)	1500-3000
Paved	Strengthening overlay	50 000-75 000
Paved	Rehabilitation	120 000-200 000

DECREASING VEHICLE OPERATING COSTS

Cost savings due to deferring the need for rehabilitation do not include savings in the wear and tear on vehicles caused by the resulting bad road surfaces. If smoother and more consistent running surfaces can be provided by regular maintenance, fuel consumption and tire and parts wear can be reduced, which leads to a lower cost of operating vehicles on the road.

Studies of road maintenance have been carried out by TRRL in cooperation with the Ghanaian Building and Road Research Institute on behalf of the Ghana Highway Authority. Figures 1 and 2, which are based on some of the results of these studies, show vehicle operating-cost reductions for different reductions in roughness at various traffic levels for both paved (6) and unpaved roads. Construction of a main road with two-lane bituminous pavement would currently cost up to $200 000. Even if this road is expected to have a life of only 10 years, the operating cost of a daily traffic of 750 vehicles will amount to a net present value of at least four times the cost of construction. This depends on whether the road is well maintained. The maintenance is usually a mixture of routine and less-frequent periodic activities. It can be carried out for an average annual cost of $1500-3000, which is less than 2 percent of the total annual cost of building the road and running vehicles on it.

If the road is not well maintained, the roughness

Figure 1. First-year savings in vehicle operating cost as result of reducing roughness of paved road.

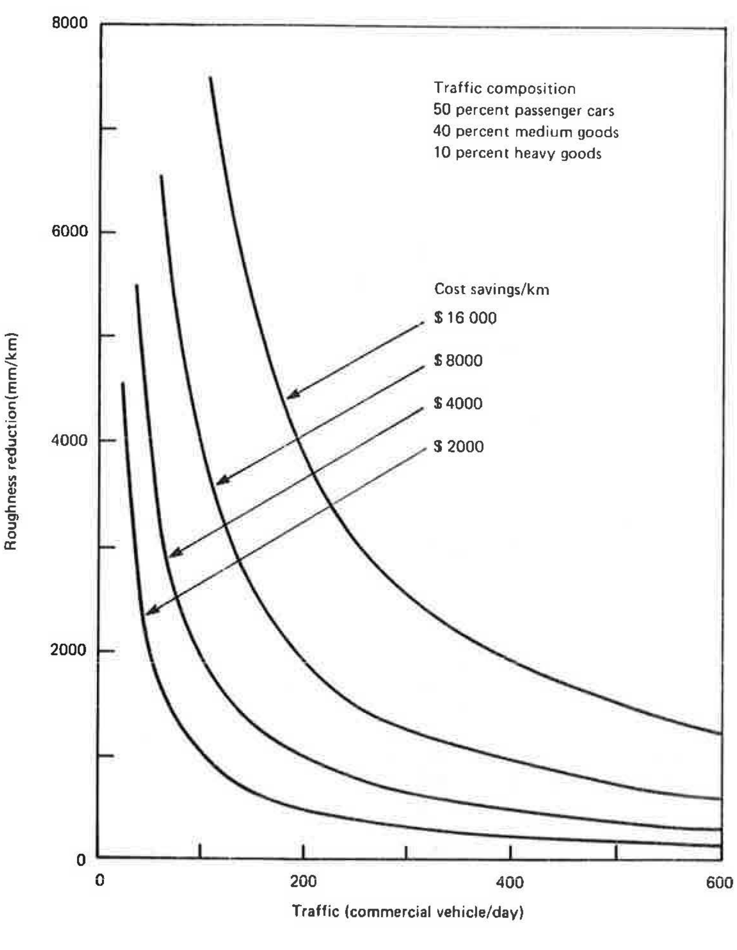


Figure 2. Savings in vehicle operating cost resulting from reduction in roughness by 2000 mm/km on unpaved road.

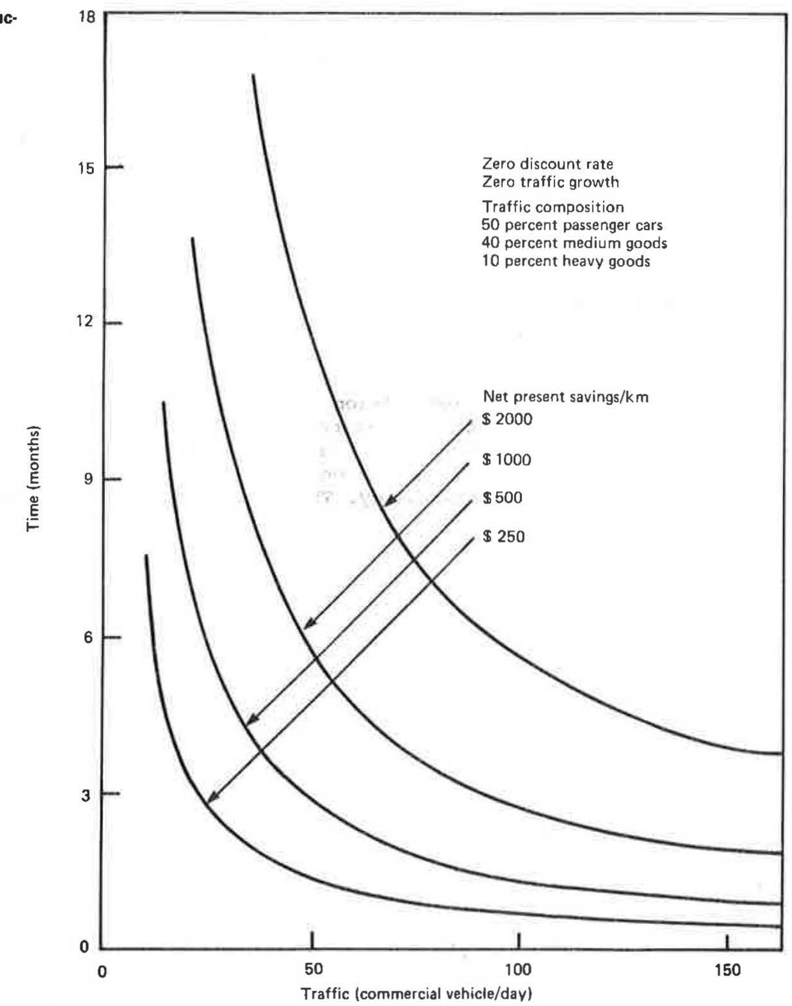


Table 2. Typical effects of roughness on operating cost for heavy-goods vehicle on paved road in Africa.

Item	Operating Cost ($/km) at RV (mm/km) of		
	2500	4500	10 000
Fuel and lubricant	0.24	0.24	0.24[a]
Maintenance labor, parts, and tires	0.33	0.49	0.91
Crew and depreciation	0.43	0.43	0.43
Standing cost	0.25	0.25	0.25
Total operating cost	1.25	1.41	1.83
Index[b]	100	113	146

[a]Subsequent research has identified increases in fuel consumption due to the deterioration of paved-road running surfaces, but these are only of the order of 1.5 percent over this range of roughness.
[b]The costs of operating light vehicles are affected more than those of heavy vehicles, while the effect on medium vehicles is slightly less.

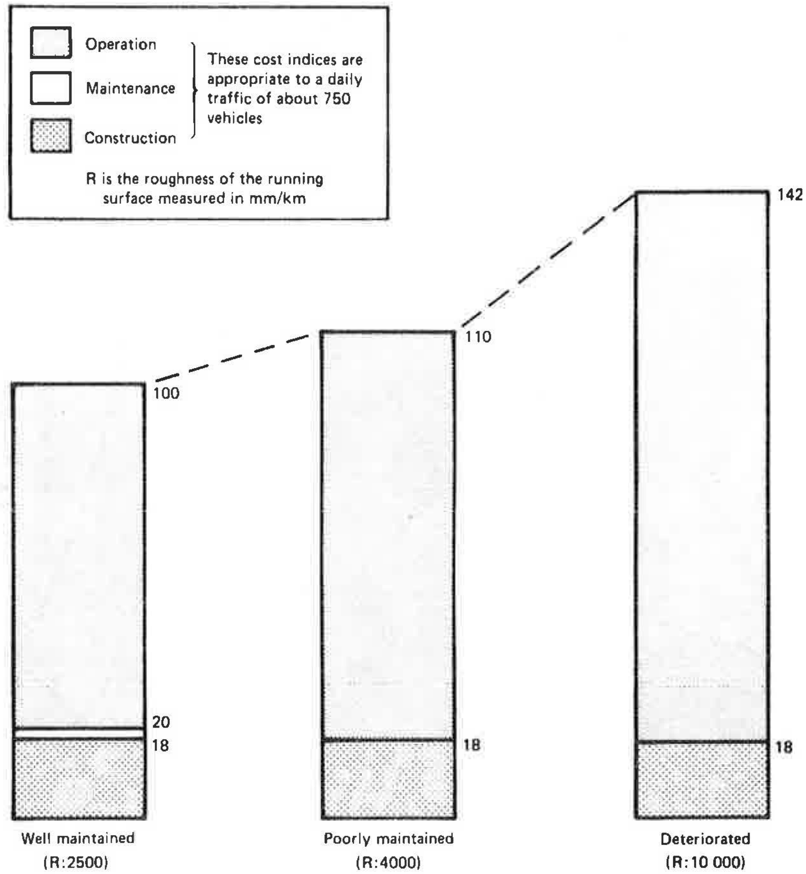
of its running surface may typically increase from 2500 to 4500 mm/km. This raises the vehicle operating costs by about 15 percent. For a daily traffic of 750 vehicles, Figure 1 shows that this extra cost would amount to more than $15 000 each year or up to 10 times the road maintenance cost. If the road is allowed to deteriorate further so that it becomes badly broken, vehicle operating costs would increase by at least 50 percent. Examples of the effects of running-surface roughness on the costs (in dollars per kilometer) of operating a vehicle are shown in Table 2. The massive increases in transport cost that result from the failure to make the relatively small investment of maintaining a road are also illustrated in Figure 3.

For example, on a 100-km length of road that carries 750 vehicles per day, the extra cost to vehicle operators because of lack of maintenance can be between $1 million and $5 million each year, depending on how long the neglect has persisted. This cost is particularly significant because it is spent on fuel, tires, and spare parts, all of which must usually be bought by developing countries with foreign exchange.

The third reason for carrying out maintenance is to keep the road open on a more continuous basis. Roads serve centers of population and industry, and if roads are closed by landslides or culvert washouts or because the surface becomes impassable during the wet season, there are serious social and economic consequences. The likelihood that a road may become impassable can be almost equally disruptive, since operators will not wish to risk getting their vehicles stuck or damaged.

A case has been noted where, in one African country, 40 percent of the vehicles fail to reach their destinations because of the state of the roads during the wet season. This resulted in closure of factories for several months because of the failure to get raw materials in and to get manufactured goods out. Agriculture suffered in a similar way because of lack of fertilizers and the failure to

Figure 3. Transport cost components for surface-dressed road.



sell produce. If industrial and agricultural goods are being produced for export, this has further serious implications for foreign-exchange earnings.

MAINTENANCE PROBLEM

Many countries are incurring high economic costs because of inadequate road maintenance. The results from Ghana indicate that a sealed pavement that carries more than 100 commercial vehicles per day is likely to justify patching and resealing if its RV exceeds 4000 mm/km and resurfacing if the roughness is of the order of 6000 mm/km. However, for these expected benefits to be achieved, it is necessary that the work be

1. Carried out to a sufficiently high standard to achieve the required improvement in pavement condition;
2. Durable, so that the maintenance input is effective for a sufficiently long period; and
3. Efficiently carried out, so that the cost of the work is of the expected order.

Unfortunately, road maintenance operations often fall far short of these requirements. Much of the maintenance work that is carried out is completed to a low standard; the result is that, for example, the riding quality of the running surface is not improved as much as was expected and patching or resealing works have much shorter lives than should have been obtained. However, the overriding problem faced by most maintenance organizations is the very small output that they are able to achieve with their resources. Studies in developing countries have shown that often the amount of work achieved in important maintenance activities is only one-fifth or less of the amount planned.

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 maintenance caused by bureaucratic processes, lack of management skills, low availability and use of maintenance equipment, and most of all by attitudes toward maintenance.

MANAGEMENT OF RESOURCES

An investigation of the difficulties encountered in managing road maintenance organizations in developing countries reveals two main factors that constrain the capacity of the organizations. These are

1. A shortage of skilled and experienced manpower, particularly in supervisory and middle-management positions, and
2. The lack of ability to obtain imported items on a recurrent basis.

These problems are particularly highlighted by the failure to achieve reasonable rates of production with the mechanical equipment that these organizations operate. Studies have shown that when mechanical equipment is working, the daily output is usually less than planned. The average availability (measured as the proportion of working days for which a resource is available to be used) of mechanical equipment used for road maintenance in developing countries is commonly of the order of 30 percent (7). It may be much lower (around 10 percent) in the case of large, specialized items such as heavy motorgraders.

The effect of such failures to use working time

Table 3. Comparison of rates of production achieved over different periods of work.

Activity	Planned Daily Output	Index of Average Output Achieved Compared with Planned Output[a] Hour	Day[b]	Month[c]
By hand				
Patching bituminous surface	0.55 m^3	100	66	25[d]
Patching gravel surface	0.92 m^3	246	160	55[d]
Cleaning ditch	36.6 m	126	86	45[d]
Cutting grass	4.18 m^2	97	92	50[d]
Reexcavating ditch	9.14 m	175	107	55[d]
By machine				
Grading gravel surface	16 000 m	107	80	9
Dragging gravel surface	24 000 m	78	72	22
Cutting grass	16 000 m	67	49	5

[a] In each case the actual output is compared with the planned output for the appropriate period. The planned output for the period is taken as an index of 100.
[b] Taking account of output lost due to failure to use working time effectively.
[c] Taking account of production lost due to nonavailability of resources.
[d] Output in labor-based activities could be increased by about 50 percent by removing dependence on transport to reach much of the work site.

Table 4. Potential for equipment-based and labor-based maintenance operations.

Activity	Potential for Equipment	Labor
Cleaning and cutting ditch	Good[a]	Good[b]
Cleaning and minor repairs to culverts and bridges	Poor	Good
Building protection against scour	Poor	Good
Repairing structures	Poor	Good
Grading unpaved surfaces	Good[c]	Impractical
Dragging unpaved surfaces	Good	Poor
Patching, sanding, or local sealing of bituminous surfaces	Poor	Good
Filling on unpaved surfaces, including shoulders	Fair	Good
Repairing slope	Poor	Good
Cutting grass	Good[d]	Good
Manufacturing signs	Fair[e]	Good[c,e]
Repairing and replacing traffic signs	Poor	Good
Marking road lines	Good	Fair
Stockpiling gravel	Good	Fair
Regraveling gravel surfaces	Good	Fair
Stockpiling chippings	Good	Poor
Surface dressing	Good[c]	Fair[c]

[a] Requires V-shaped ditch.
[b] Requires trapezoidal ditch.
[c] Requires skilled operators.
[d] Depends on width of shoulder and presence of obstructions such as road furniture and culvert headwalls.
[e] May require specialized equipment.

is illustrated in a summary of field measurements in Table 3 (8).

The severe shortfall in the availability of equipment has three main consequences:

1. Output is directly reduced in those activities (such as grading) for which the equipment is the prime requirement.
2. There is a constraint on output in activities for which the equipment has a supporting function (such as in providing transport for labor to reach more remote sections of the road network).
3. When several items of equipment are required to work together (as in surface dressing, for example), the effects of their poor availability tend to be cumulative. The work of most maintenance organizations is, either directly or indirectly, heavily dependent on mechanical equipment and therefore much affected by its poor performance.

In the maintenance organizations of many developing countries, the true costs of owning equipment are not well understood. Commonly only running costs are accounted, so the losses arising from equipment that stands idle are neglected. In view of the low efficiency with which equipment is used, investment in it is extremely costly in relation to the small amount of maintenance that is actually accomplished.

In response to this situation, it is desirable to concentrate equipment on the most important tasks for which there are no satisfactory alternative techniques. Steps should also be taken to improve the support of this limited amount of essential equipment so that at least its availability and use can be improved. The effectiveness of the equipment-based and labor-based techniques for various maintenance activities is shown in Table 4. This indicates the activities, such as grading and surface dressing, on which the limited equipment capacity should be concentrated.

In contrast to the constraints on the effective use of equipment, labor is often readily available. In this case its employment usually involves a very low opportunity cost. Moreover, as is shown in Table 4, labor-based techniques are suitable for a number of maintenance activities. Extensive studies have shown that for the equivalent construction activities, labor methods are likely to be cheaper than those based on equipment where the labor rate is less than about $5/day (9). In addition, studies have shown that the availability of labor is generally far more reliable than that of equipment in developing countries. Particularly when managed on a task-work basis, laborers have been found to achieve close to planned standards of productivity, whereas the accomplishment with equipment usually falls far short.

Thus in road maintenance, where the productivity of equipment tends to be particularly low, there is a very strong case for adopting more labor-based techniques when these are practical alternatives. However, the quality and productivity of labor-based work is very dependent on the quality of supervision, and supervisors require special training to equip them with the skills needed to manage large labor forces.

The choice between equipmentand labor-based methods affects the basic organization of road maintenance. Equipment-intensive works favor a more centralized organization, whereas labor-intensive works favor decentralization. If labor-based methods are to be used, other changes are also needed in the organization of work. It is important that good work procedures be established and that the correct tools be available for the job. If labor is expected to work efficiently, appropriate tools of an acceptable quality must be provided. However, it should be increasingly possible to achieve this within the capabilities of local manufacture.

BUDGET ALLOCATION

Roads departments in all countries of the world have an obligation to spend their budgets effectively and in such a way to achieve the best value for the 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 levels.

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 from declining. This can be achieved only by providing appropriate, effective, and timely maintenance. Such provision should therefore be the first priority for budget allocation.

Once funds have been allocated to preserve the existing system, the next objective should be to try and maximize 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 little 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.

There is also a need to establish priorities for budget allocation at the district or operational level and this should follow the same guidelines as above. Priorities should be as follows:

1. Maintenance;
2. Upgrading, strengthening, and reconstruction; and
3. New construction.

The setting of priorities for upgrading and new construction are beyond the scope of this paper. However, a simple method of setting priorities for maintenance at the district level will be described. This is based on recommendations given by TRRL (10), which have been prepared by the Overseas Unit in collaboration with Scott Wilson Kirkpatrick and Partners, Consulting Engineers.

SETTING MAINTENANCE PRIORITIES

The first step in setting maintenance priorities at the district level is to establish what the total maintenance requirement of the district is. This can only be determined by carrying out inspections to assess the condition of the road. Methods of carrying out road inspections have been described elsewhere (10). The road conditions recorded in the inspections should be compared with maintenance criteria such as those in Overseas Road Note 1 (10) to determine what maintenance needs to be carried out.

The rate at which running surfaces deteriorate and the consequent frequency and extent of carriageway and shoulder maintenance are closely related to the nature and volume of traffic on the road. A knowledge of traffic loadings not only will indicate which roads are likely to deteriorate most quickly, but will also assist in establishing priorities for maintenance based on the use made of individual roads. It is therefore necessary to have reliable information about traffic and to carry out counts to provide this.

A simple road maintenance classification based on traffic should be introduced, such as that shown below:

Category	Average Daily Traffic	Surface Type
A	>1000	Paved
B	500-1000	Paved
C	200-500	Paved
D	>200	Unpaved
E	<200	Paved
F	50-200	Unpaved
G	<50	Unpaved

It is useful to have detailed information about the engineering characteristics and distributions of soils in the district. This enables account to be taken of their influence on road performance, particularly in terms of subgrade strength and drainage. This also helps the search for suitable maintenance materials. Information collected in this way will help to provide guidance on assessment of priorities.

It is unlikely that sufficient resources will be available to carry out all the work on remedial and preventive maintenance that is indicated by the inspections. Consequently, decisions must be made about priorities. The first step is to estimate the total amount of work that needs to be done, as indicated by applying maintenance criteria to the field inspections. The amount of work can be grouped under the following headings:

1. Routine (activities required irrespective of traffic level): cutting grass; clearing drains; recutting ditches; and maintenance of culverts, bridges, and road signs;
2. Recurrent (traffic-dependent activities): patching, dragging, and grading of gravel roads; crack sealing; edge repairs; and patching and road marking of paved roads;
3. Periodic (activities required at intervals of several years): regraveling of gravel roads and surface dressing and resurfacing shoulders of paved roads; and
4. Urgent (nonprogrammed activities): all emergency operations required when a road is cut.

It will be necessary to allocate the limited resources in the way that most nearly satisfies the objectives of maintaining the road system to the desired standard. Sophisticated methods have been developed for making allocations of constrained resources but the maintenance engineer is unlikely to have either the data or the facilities necessary to apply them. It will therefore be necessary to set up a system for resource allocation.

The following order of priorities is recommended:

1. Urgent work,
2. Drainage work,
3. Recurrent work on pavements,
4. Periodic work, and
5. Other routine work.

The need to give absolute priority to urgent work is self-evident, and sufficient funds and materials must be reserved for this. Routine drainage work should always be given high priority, since neglect of this can quickly lead to deterioration of the whole road. It should not be inferred that all drainage work must take precedence over all recurrent work on pavements. The point to keep in mind is that repairing surface defects that result from faulty drainage is a waste of effort unless the drainage is also corrected. Once funds have been allocated for the first three categories, a balance should still be available for periodic work. Periodic work can be considered as a series of discrete projects that can be carried out independently, can be deferred or brought forward as required, and can compete with each other for funds. Other routine work is of low priority.

Urgent work should be carried out on an immediate basis and will not be planned in advance, although resources will have to be reserved for it. All other work should be planned according to the basic list of priorities extended to take account of traffic as shown below:

Type of Work	Priority by Traffic Category A	B	C	D	E	F	G
Drainage	1	2	3	4	5	6	7
Recurrent work on pavements	8	9	10	11	12	13	14
Periodic	15	17	19	21	23	25	27
Other routine	16	18	20	22	24	26	28

This is used to prepare a list of maintenance tasks in order of priority. The order of work in the list should then be changed when necessary to take account of soils, topography, climate, and other features that are known to affect the maintenance requirements.

Depending on the way that maintenance is organized within the district, the funds available for routine, recurrent, and periodic maintenance may not be interchangeable. Routine and recurrent maintenance will often be carried out by crews based at the subdistrict level or in road camps. In this case, each subdistrict should carry out their work in order of priority taken from the master list. Periodic maintenance work organized directly at district level should have its priority assessed in the same way.

DISCUSSION

Many countries are incurring extremely high costs because of inadequate maintenance on their road networks. Lack of effective maintenance is leading to the need for premature rehabilitation of roads, is causing high vehicle operating costs, and results in high costs for industry and agriculture.

Generally, more resources are needed for road maintenance, but there are also other constraints such as the low availability and use of mechanical equipment, the lack of management skills, bureaucratic processes, and, most of all, attitudes toward maintenance at all levels. There is a need for the introduction of better equipment-management methods, and where equipment availabilities are low, there is considerable scope for carrying out many maintenance activities by using labor.

If there are insufficient resources available to maintain the existing road network, any additions to that network will mean that those resources must be spread even further with the result that the effectiveness of maintenance will decline even more. In many countries, national development would be accelerated if resources were diverted from new road construction or major upgrading to concentrate on maintaining the existing road network. In order to achieve this, demonstrations of the large benefits from maintenance should be given to government ministers in order to seek the required changes in budgetary policy.

Meanwhile, in most countries the resources that are currently devoted to road maintenance are being used very ineffectively. Much of the work that is carried out is completed to such a poor standard that it has to be repeated much sooner than should be the case. However, the most serious aspect is the very low use of resources. This is particularly true of equipment, much of which is active for less than one-tenth of the time that it should be. There are many causes for this situation, but fundamental constraints are the shortage of skilled and experienced personnel, particularly at the middle-management and technical-supervisor level, and an excessive dependence on imported resources.

When funds available for road maintenance are limited, it is necessary to set priorities for their application at both national and local levels. It is recommended that the funding of maintenance have priority over the funding of upgrading and new construction, since this is necessary in order to preserve the existing investment in road infrastructure. A simple method has also been described for setting road maintenance priorities, which is based on the recommendations made in Overseas Road Note 1 (10).

It is very important to recognize the true capacity of the maintenance organization so as to identify priorities among national road maintenance requirements. This will ensure that the present limited maintenance capacity can be applied where it will be most effective. Such a strategy will tend to concentrate on the most heavily trafficked roads and will generally involve preserving roads that are in reasonable condition rather than rehabilitating those that have deteriorated appreciably.

Thus, much can be done to improve current maintenance by working within the existing system and within the current financial limitations. A road is a major capital investment, which should be expected to show an adequate return on expenditure. Failure to maintain the road properly leads to rapid deterioration with consequent increases in vehicle operating costs and accidents and the need for expensive reconstruction. Maintenance is therefore an important and worthwhile contribution to the economic well-being of the country and an effective road maintenance organization is a valuable part of its economy. Professional engineers concerned with maintenance must work in a professional manner and set a personal example by their own attitude toward maintenance. By being involved in maintenance and by doing a good and effective job, it is possible to make a much bigger contribution to the economic development of a country than by being involved in new construction.

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Maintenance and Rating of the Condition of Gravel Roads in Finland

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Factors connected with the summer maintenance of gravel roads in Finland are discussed. The gravel roads have been divided into five maintenance classes on the basis of average daily traffic. The amount of maintenance operations (dust binding, graveling, grading, and dragging) depends on the road maintenance class as decided by the Road and Waterways Administration (TVH), which is responsible for the maintenance of public roads. The local road authorities (maintenance supervisors) decide when the gravel road requires maintenance by using the quality standard of TVH. The condition of the road has been described by five different classes (0-5), each of which has been given a minimum service level below which the condition of the road may may not fall. Because the determination of the service level depends on the subjective view of the person evaluating the condition (maintenance supervisor), the Road and Traffic Laboratory at the Technical Research Centre of Finland (VTT) made a test in which the condition of a road determined by using the quality standard (0-5) was compared with the condition of the road measured with a bump integrator (in centimeters per kilometer). The results showed that it is possible to determine the road condition with subjective evaluation based on the quality standard so that it correlates well with the roughness measured with the bump integrator. The Road and Traffic Laboratory used a bump integrator to study how the condition of the road changes after grading when the traffic volume increases before the next grading. The tests were made on three gravel roads that had an average daily traffic of less than 500 vehicles. The result shows, for example, that in normal weather conditions the condition of the road starts to deteriorate considerably when the traffic volume is about 8500 vehicles after grading. During a long dry period, deterioration is clearly faster.

The length of the public road network in Finland is about 75 000 km; 50 percent are gravel roads, 30 percent have oil-gravel surfacing, and 20 percent asphalt concrete surfacing. The Roads and Waterways Administration (TVH) is responsible for the condition of public roads. It comprises the Administration and 13 road and waterway districts that have been divided into 172 maintenance areas, each headed by a maintenance supervisor. The maintenance area is responsible for all maintenance operations in the area that are within the scope of TVH and for the tasks given by the road and waterway districts.

The maintenance of gravel roads is divided into winter and summer maintenance. The former includes removal of snow and de-icing (sanding and salting); the latter includes dust binding, graveling, grading, and dragging. In addition, on gravel roads the structure must be improved; i.e., the bearing capacity of the road must be improved and the gravel road surfaced. Although traffic and transport account for only about 12 percent of gravel road kilometers, summer maintenance and structural improvement of these roads require more than 25 percent annually of the allocations reserved for the maintenance and strengthening of the public roads in Finland.

This paper deals with the summer maintenance of gravel roads, which in Finland extends from April to November, seven to eight months. The permitted axle load and multiple-axle load are generally 10-16 tons. In spring during ground thaw the weight of the vehicles must be restricted on road sections that have weak bearing capacity, about 7300 km of gravel roads in 1981 (20 percent of the total length of gravel roads).

The planning of gravel road maintenance follows the maintenance standards of TVH (1). The standards divide the gravel roads into different maintenance classes, give the material and work quotas for different maintenance works, give each maintenance class a minimum service level, and also give information on various work methods, duration of work, and costs.

The maintenance classes of gravel roads are divided into five classes on the basis of average daily traffic (ADT) as follows:

Maintenance Class	ADT	Length of Gravel Road (%)
3	1501 - 6000	0.1
4	501 - 1500	1
5	201 - 500	17
6	101 - 200	37
7	≤100	45

The amounts of material and work expended vary annually, depending on the weather, and therefore the values given in the standard are the means of five years. In considering the differences between the amount of work in different maintenance areas, a so-called condition coefficient is used, from 0.8 to 1.2. The quantity standards are used when the annual maintenance budget is drafted, in allocation of resources, and in planning the maintenance operation during the work period.

The amounts of calcium chloride ($CaCl_2$) used annually for dust binding on gravel roads and the average amounts of crushed gravel used annually in summer maintenance of gravel roads, by maintenance class, are given below:

Maintenance Class	Width of Road (m)	Material Used: $CaCl_2$ (tons/km)	Material Used: Crushed Gravel (m^3/km)
3	4	-	-
	5	-	-
	6	5.0	69
	7	5.2	72
4	4	-	-
	5	3.4	55