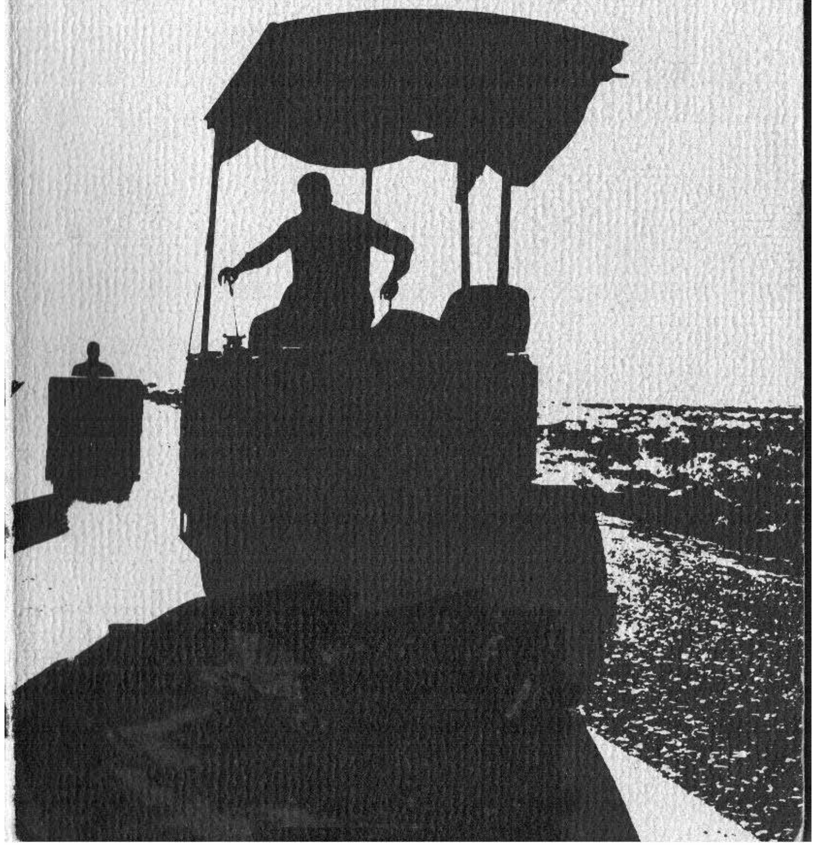
The Road Maintenance Problem and International Assistance

World Bank, December 1981



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Foreword

Among problems in the growth of developing countries' highway transport systems, development of effective road maintenance is both the most important and the most intractable; experience has demonstrated that building institutional capacities for road maintenance is far more difficult than building roads. In order to better understand its own experience and draw lessons for future efforts, the World Bank in 1979 conducted a special study leading to a report entitled "The Highway Maintenance Problem" (April 1979). In February 1980 the Bank invited other development aid agencies to a meeting at its offices in Paris to discuss the maintenance problem and seek consensus on ways to overcome the difficulties. Two documents were derived from that meeting:

- A revised version of the World Bank's earlier paper, expanded, as suggested at the meeting, to encompass the special problems associated with low-volume rural roads, and hence retitled "The Road Maintenance Problem."
- A summary recording the consensus of the Paris meeting on key issues, entitled "International Assistance for Road Maintenance."

These two documents are reprinted here and will be circulated widely by the World Bank in order to broaden public understanding of the important problem of road maintenance.

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Vice President, Projects Staff

Part One
The Road Maintenance Problem

Overview

Development of effective road maintenance is of great importance to the growth of countries' highway transport systems. Yet its development remains an intractable problem.[1] Maintenance has increasingly come to the fore in the developing countries since the completion, in the late 1960s and early 1970s, of extensive additions to national trunk networks and with the aging of sections that were built earlier. Current construction of many new secondary and rural roads adds to the maintenance work load. Countries are increasingly recognizing the importance of maintenance and looking to the World Bank for assistance.

While the Bank has long been concerned with the maintenance problem and the development of maintenance systems, its experience—gained equally through projects specifically devoted to this purpose and through maintenance covenants in highway construction loans—also shows that building up the necessary institutional capacities for maintenance is much more difficult than building road networks. No maintenance development effort with which the Bank has been involved was foreseen as being of more than ten years duration. Yet none has taken less than ten years in practice.

This paper is an attempt to distill the results of the Bank's experience and of the research that it has conducted during the last ten years on the economics of highway construction and maintenance, with a view to identifying approaches and solutions that seem to work better than others. The focus is largely on the still unresolved problems of national highway maintenance; but since rural roads suffer, often to a magnified degree, from the same problems, they, too, can benefit from many of the measures suggested, although they often require approaches that mobilize more local or regional capacities and resources.

The history of the Bank's involvement in highway maintenance is one of increasing emphasis in its highway operations on this problem area and increasing specificity in maintenance covenants, maintenance projects, and terms of reference for consultants. The general conclusion of this review is that this emphasis should be further extended, in full recognition of the maintenance problem as a structural and institutional one. The justification for Bank financing in this area is not so much one of expected physical impact of the hardware

[1] The words *highway* and *road* are used synonymously in this paper except where otherwise specified in context.

provided as it is of the contribution such lending and related arrangements can make to development of the institutional framework that is needed to ensure adequate performance of continuous maintenance.

Highway construction and maintenance form an integrated cycle over time that needs to be adjusted to the conditions of a particular road, its physical state, and the growth of traffic. Earth roads need *routine* maintenance—that is, operations repeated one or more times every year—such as ditch cleaning, pothole filling, grading, and control of vegetation. Normally, it is worthwhile to construct a road to gravel standard when traffic reaches fifteen to forty vehicles per day. Regular routine maintenance of gravel roads is also needed, in addition to *periodic* maintenance—that is, operations repeated every five to ten years—in the form of regraveling. Construction of roads to paved standards is normally warranted when traffic volumes reach 200-500 vehicles a day. Routine maintenance of paved roads also includes patching of cracks and special attention to shoulders and pavement edges, while periodic maintenance takes the form of bituminous-surface dressings or seals. A further type of operation, partially substituting for maintenance but substantially improving the road, is upgrading or betterment, such as asphalt overlays and minor improvement of drainage and alignment. Finally, maintenance of the *equipment* used for maintenance itself is needed.

Many countries have tried to economize by adopting time-staging strategies for paving—that is, starting with a relatively inexpensive pavement and strengthening it in time as traffic grows. The Bank's research on strategies of alternative highway construction and maintenance suggests that, while this is theoretically the best approach, it can easily become much more costly (in terms of present worth of total costs) if subsequent maintenance does not reach the high standards and timeliness assumed. Loading of vehicles much beyond legal limits is also widespread in developing countries, particularly on main roads, and can do severe damage to pavements. Thus, plans for new construction must take these risks—overloading of vehicles and inadequate maintenance—into account, while pavement underdesign in the past makes maintenance and provision for strengthening measures such as overlays even more important than they might be otherwise.

At current prices,[2] for example, effective routine and periodic maintenance of paved roads can be carried out for about $1,500-$3,000 a kilometer (including the necessary equipment charges) as a networkwide average. Even if traffic on a road comes to only 250 vehicles a day, the resultant savings on vehicle operating costs will be about $5,000-$6,000 a kilometer annually. Savings will be much greater, of course, as traffic increases. Regular maintenance can also enable rehabilitation or overlays to be postponed for five years or longer. Postponement can save substantial amounts of capital charges

[2]All prices are as of June 1980.

given today's prices—about $50,000-$75,000 a kilometer for an overlay and $120,000-$200,000 a kilometer for full rehabilitation of a two-lane paved road.

Recent experience of the Bank shows that the estimated overall economic returns on proposed maintenance projects are very high—higher than those on proposed road construction projects: an average of 40 percent or more, for instance, on eight major maintenance schemes supported by loans in fiscal 1978, while the average was only 24 percent on all the new construction for which the Bank made loans in that year. High returns seem to have been achieved, too. Completed maintenance projects show returns at ex-post audit that are sometimes several times the opportunity cost of capital and only very rarely beneath it, even in cases where physical achievements fell substantially short of forecasts. The high returns basically reflect the great profitability of small expenditures to maintain the full-service value obtainable from very large earlier investments in construction. But they also suggest that some shift of additional resources into maintenance would be worthwhile in many countries.

The broader purpose of Bank projects is to enable maintenance to be carried through effectively and then sustained. The problems are generally greater than can be dealt with simply by a covenant requiring good maintenance or adequate funding. In a few countries, one constraint—such as insufficient budgetary allocations, inefficient use of the available resources, or inadequate staff—is clearly dominant. In most countries, however, the situation is much more complex. Budgetary allocations are insufficient, in part, because the finance ministry has little faith that the funds will be spent efficiently. Inefficiency is often closely connected with poor training, motivation, and organization of staff and diversion of their efforts to other works. These deficiencies in part are the result of inadequate incentive structures and a shortage of financial resources. Yet it is not worthwhile—and may not be politically possible—to loosen the financial leash unless efficiency improves. In many countries, there are, at one and the same time, both a need for additional regular funding and scope for reduction of costs.

In some ways, "capacity building" is a better description of what needs to be done than institution building in view of the narrow interpretation sometimes given the latter expression. The creation of legal and administrative structures and institutions and the clarification of responsibilities for maintenance in general or particular parts of the task is an area in which Bank-assisted projects have had the least difficulties. Although reorganization has often been delayed, it has usually been done. The problems have arisen more in filling out the new organizational structures with adequate staff, developing the necessary discipline, providing needed operating funds, and reaching an effective level of day-to-day functioning on a countrywide basis.

The main burden of this type of work within a ministry of public works is normally carried by a few key nationals—whose dedication and leadership can often make the difference between success and failure—and by foreign consultants and technical assistants who have been vital to such advances as have been made in almost all Bank-supported maintenance projects. The job of a consultant in maintenance is both difficult and delicate. It involves adjusting to local attitudes and cultural factors as much as solving technical problems. In addition, a careful balance has to be maintained among the many resources assembled to perform maintenance, many of which, like attitudes and staff capacities, have to be developed gradually. A country's absorptive capacity for consultants and technical assistance can increase in time. Maintaining a good balance, therefore, is partly a matter of foresight on the part of the consultants assisting the program and partly a matter of defining and structuring their terms of reference and the physical components of the project realistically—in many instances phased over longer periods than have been thought necessary.

A central task in capacity building, but one where the appropriate balance has been particularly difficult to achieve, is that of staff training. The Bank has long supported such training, through financing physical facilities, training equipment, foreign trainers, and overseas scholarships. It is continuing to deepen its involvement. In the past, programs have often been too small, too partial, too desk dependent, or too little related to the abilities of existing staff. Proper planning has to be based on a comprehensive, forward-looking analysis of the prospective balance between changing skill requirements, at different levels and in different specialties, and prospective availabilities from existing sources; allowance has to be made for losses of staff to the private sector that are typically high. Planning requires an early appraisal and inventory of staff and their educational attainments, just as engineering works require the collection of basic data on soils and hydrology.

To give it sufficient continuity, status, and weight in broader policymaking within the highway department, the whole function of training or staff development, for all levels, from senior engineers and managers to patrolmen and drivers, needs to be institutionalized. Training efforts have too often been seen as one-shot affairs, without allowance for the fact that 10 percent or more of the staff may need to be replaced each year because of retirements and losses to the private sector and that remaining staff will need refresher courses. Current maintenance training programs supported by the Bank usually provide for at least brief training of between a tenth and a fifth of total staff above the grade of laborer each year. Although most countries have, by now, set up training sections in their highway departments, many need to be upgraded to higher administrative standing.

Discontinuity of training efforts has been an unfortunate and frequent problem in the past. It would be highly desirable for the Bank to find administratively simple means of providing, as a last resort, the small amount of financing sometimes required to sustain efforts between the completion of one project and the initiation of another. Such financing could perhaps be found through the Project Preparation Facility or some other similar arrangement.

With reasonably efficient operations, the amount of money required for maintenance of a highway network is not great. Some 2 percent, or slightly less, of the road capital stock (replacement or updated original investment value) is generally sufficient to cover a year's requirements for routine and periodic operations, as well as maintenance and renewal of the equipment involved. This sum seldom represents more than a fraction of annual government revenues from road users and, provided it is efficiently spent, almost immediately repays itself several fold.

But the funds do need to be provided on a regular and timely basis, even in face of sharp budgetary fluctuations. If they are not, then the costs to the country—first, in the form of extra operating costs (with a substantial foreign exchange component) for road users, and soon after, in the form of claims on the public treasury for rehabilitation and reconstruction—become much higher. New construction can be postponed during periods of financial stringency, but very little maintenance can be. Automatic mechanisms, such as road funds for channeling sufficient resources into road maintenance, have not generally proved to be effective; in the face of budgetary stringencies, such funds have been diverted, in one way or another, to other purposes. The solution to the problem must be found through fiscal and administrative discipline, advance planning, and wider recognition of the economic importance of maintenance.

Sub-Saharan Africa faces special problems because of the sparseness of population in relation to the large size of the countries and of the heavy dependence on foreign economic assistance. On the one hand, sub-Saharan Africa is already devoting to road maintenance twice as high a proportion of national gross domestic product (GDP) as developing countries in other regions, while minimally adequate maintenance would require that it devote 50 percent more, or three times as much as other countries. On the other hand, foreign assistance agencies working in the highway field have generally been prepared to cover about three times as high a proportion of the total costs of road construction (and reconstruction) as of road-maintenance projects; because foreign aid is such an important factor in the total public expenditure allocations, the readiness of foreign assistance agencies to cover road construction costs has created some bias against maintenance.

The Bank's policy in financing maintenance has generally been to lend for capital expenditures, roughly defined as those that yield benefits through a period of five years or longer. This policy has meant that, in practice, the Bank has lent readily for technical assistance and training, construction of workshops, procurement of maintenance equipment, rehabilitation of existing equipment, initial inventories of spare parts, and any periodic maintenance operations, whether carried out by force account or by contract. The Bank has thus been able to lend—and in Africa has lent—for a considerably higher proportion of the total costs of maintenance projects than most other suppliers of aid have normally done. On the other hand, like them, it has very seldom lent funds to cover any part of the operating costs of routine maintenance.

The Bank lends funds to support national or regional maintenance programs or parts of them—such as systems of routine maintenance, periodic maintenance of gravel or paved roads, or maintenance of equipment. One aspect of program formulation is to minimize the economic costs of each type of operation; thus, efficiently run, labor-intensive techniques can be emphasized where unskilled labor is plentiful. Another aspect is to obtain the best possible combination of the maintenance operations that must be undertaken on the various classes of road in the network, in principle, carrying each operation to the point at which it yields a marginal return that is equal to the opportunity cost of capital. To avoid hiding low-priority operations within a broader program, it is helpful to consider what amounts of which operations would be sacrificed in the event of, say, a 20 percent reduction in annual appropriations for maintenance operations and what would be added with a 20 percent increase, and then to determine the returns on these decremental and incremental expenditures.

The resultant savings in vehicle operating costs, particularly in vehicle maintenance and tire wear, are normally of overriding importance within the total returns on maintenance expenditures. These savings are estimated on the basis of road tests and user surveys regarding operating costs on roads in different conditions, plus surveys and inventories of the state of the network and an assessment of the improvements that different maintenance operations will bring about. Other important benefits are postponements of major expenditures that would otherwise become necessary for rehabilitation and reconstruction and avoidance or reduction of closures—for instance, of unpaved roads in the wet season.

The Bank's approach reflects the basic proposition that ultimate responsibility for maintenance, including, in particular, the recurrent costs of routine operations, should be that of the borrower. The reluctance of the Bank to finance such recurrent costs has undoubtedly strengthened financial and administrative discipline and has been responsible for increased government support for these expenditures in many countries.

But this policy has, at times, been in conflict with the basic capacity-building purpose of the Bank's lending for maintenance, and may, to some extent, have inhibited an appropriate focus by Bank and borrower on building up capacity for routine maintenance where this is the most critical need. Where budgetary constraints are as tight as in many sub-Saharan African countries, this stringency has sometimes caused equipment to lie idle for long periods for lack of fuel, materials, and spare parts, thus resulting in inefficient use of personnel. Also, in many countries, regular government funding is most critically needed for keeping inventories of spare parts at a satisfactory level, but the short-run injections of spares sometimes financed by the Bank have not contributed substantially to a permanent resolution of the problem.

Therefore, the focus of future lending by the Bank will be on the overall objectives and priorities of maintenance programs and the development of local efforts and institutions to the point that the most cost-effective combination of routine and periodic maintenance, equipment maintenance, and renewal might be realized. Emphasis will be placed on the increase, in time, in the proportion of *total* maintenance outlays, capital as well as recurrent, financed domestically, but the particular application of Bank or International Development Association (IDA) funds within the maintenance field will be chosen by reference to what would contribute most to strengthening the effectiveness of the maintenance institutions. In special cases, in the poorest countries, where an expanded financial commitment by a government is, over a period of time, being asked for, and where there is critical shortage of funds—such as for fuel and spare parts—the Bank will be prepared to finance a part of the incremental recurrent costs, normally on a declining share basis, during the development period. Financial covenants will reflect the great importance that the Bank attaches to appropriate increases in government shares over a period of time.

The problems of accounting and charging for equipment and of finding regular domestic arrangements for keeping inventories of spare parts at adequate levels will be given greater emphasis in Bank policy. Autonomous funds for equipment, fed by hire charges from users of the equipment, already exist in principle in many countries and have substantial potential advantages for improving efficiency in the management and use of equipment. Such funds can also facilitate the financing of replacements in those quite numerous better-off countries that should be able to finance the replacement of equipment out of their own resources. Equipment funds could be strengthened by following more fully commercial accounting procedures. This strategy would be supported by having portions of Bank highway loans for equipment on-lent by the government at harder commercial terms, as is now sometimes done with funds destined for credit institutions. Phasing of Bank-financed procurement of equipment over periods of years could also facilitate efficient management and eventual renewal of equipment. Arrangements for local provision of the small amounts of foreign exchange required to replenish inventories of spare parts are critically important. They should be worked out to succeed any lending for initial inventories of spare parts and should be reflected, as necessary, in covenants concerning maintenance financing.

Rates of availability, use, and productivity of maintenance equipment are at present very low in many countries and therefore present a significant area for improvement in efficiency and for overall reduction in costs. Detailed recording and reporting systems, which tend to be more accurate when the equipment budget is autonomous, are essential instruments of management in the equipment field. The Bank has begun to work out with some borrowers "action plans" detailing measures designed to improve the efficiency of maintenance operations throughout the project period. The direction and followup of such action plans are based, in large part, on the borrower's own internal management-information system. Equipment performance, an aspect of maintenance that needs most to be pursued in this manner, can be improved through action plans prepared with input from experienced mechanical engineers.

Another significant way to improve maintenance efficiency and reduce costs is through greater recourse to the private sector. The use of contractors can reduce the burden on scarce government staff and can also reduce costs as a result of competitive pressures for efficiency—pressures that are hard to duplicate under civil-service arrangements. An even flow of relatively small jobs, such as maintenance can provide, is, moreover, an ideal way of fostering a nascent domestic contracting industry. Periodic maintenance is normally contracted out in many of the more advanced developing countries, as are specific jobs, such as the supply and transport of materials. Ways are now being found to contract out routine maintenance also.

Many consultants appear to have placed excessive emphasis on elaborate management-information systems, even in countries greatly lacking in staff and facilities. Under these conditions, the need seems to be more for a direct focus on the essential, if difficult, task of developing simple but highly disciplined inspection and supervision systems for field operations. Written reports should be limited largely to existing accounting and work-order practices. Maximum emphasis should go to actual execution of both regular and unexpected inspection visits by supervisors at each level to units under their charge. The prime object is to develop a shared concept of standards and a strong sense of responsibility for keeping to those standards through whatever effort is necessary. The next step would be to create a small organization-and-methods section at headquarters to conduct ad hoc studies. Only at this stage, and provided that the equipment information system is already functioning without problem, should more elaborate field reporting systems be attempted.

At later stages in development, there can be a more systematic collection of planning data and a regular comparison of budget and plan against actual in many of the Bank's borrowing countries that are better supplied with educated manpower. These systems should be built gradually, however, and in response to need. Regular traffic counts, for example, using a proper sampling basis and with adequate checks, should be made first on roads that carry at least 100-200 vehicles a day. If focused on situations and types of data that provide scope for management choice, information systems can help significantly to increase efficiency in the allocation of resources by identifying problem sections in the network and by revealing areas of operational inefficiency.

Even then, public attitudes and public interest will continue to be of great importance. They will affect both the resources allocated to maintenance and the standards of performance that the highway authorities will try to attain. They will also impinge on the treatment of roads by the users themselves—in regard to overloading trucks, for instance, a problem that cannot usually be solved except by close

cooperation between the government and associations of truckers. The Bank is attempting to help the growth of general associations of road users and similar public-interest groups by such means as the provision of comparative country statistics and general documentation.

The Bank will also seek the cooperation and support of other lenders and aid agencies in meeting maintenance objectives. While borrowing countries appear to have appreciated firm stands taken by the Bank on the importance of improving and adequately financing maintenance, there have been instances in which the Bank's position has been undermined by the readiness of other agencies to undertake further new highway financing. In other instances, in which spare parts were of the highest priority, difficulties have arisen from the reluctance of some lending agencies to share in their financing. Thus, it would appear to be worthwhile to pursue efforts to develop more mutually supporting approaches with other financing agencies and borrowers.

Even though borrowing countries have often fallen short of meeting relevant loan covenants and project objectives, the Bank has played a useful role in the development of maintenance capacity, and it has improved, in recent years, the quality of its assistance. The emphasis it has given to road maintenance will continue and expand, both in its assessment of the eligibility of countries for further highway lending and in the composition of new projects. More specific action plans, training programs, budgetary arrangements, and administrative systems will be sought. The Bank will work with governments to agree on targets and control mechanisms by which progress can be judged and guided.

Introduction

Highway maintenance is a problem that affects both rich nations and poor nations. But it is particularly serious in most countries that borrow from the World Bank. The Bank has long been concerned with the maintenance of national highway networks, and developing countries are increasingly looking to the Bank for help and advice on how to improve their maintenance systems. Greater emphasis by the Bank on rural development in the 1970s and much more lending for construction of rural roads raises maintenance needs further. Yet maintenance has been an area of rather limited success in the Bank's earlier lending for highways and roads.[1]

This paper is a reexamination of the economic priority of highway maintenance and its importance in development and a report on the solutions that seem to work in practice. Use is made of the research on standards and strategies for highway design and maintenance that the Bank has conducted during the last ten years in conjunction with institutions in England, the United States, France and, subsequently, Kenya, Brazil, and India; this research has produced a fairly comprehensive computer model, which has now been applied in several cases, for analysis of road investment and maintenance decisions. In addition, special reviews have been made of past projects financed by the Bank and IDA with maintenance objectives and components and, in particular, of certain programs that have worked better than others, despite difficult circumstances. These reviews have tended to show that there is still quite a long way to go in improvement of maintenance, even in these cases.

In the course of the investigations, various questions have arisen about Bank policies and advice with regard to highway maintenance and its financing, and this report contains some suggestions for strengthening them.

The basic issues that the paper tries to illuminate, therefore, include:

- How can the adequacy of maintenance be measured?
- How does one decide what is an appropriate expenditure on maintenance and on various components of maintenance programs?
- Why do many governments appear to spend too little on highway maintenance?

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[1]All references to the World Bank in this paper are deemed to refer also to the International Development Association (IDA), unless the context requires otherwise. The fiscal year of the two institutions runs from July 1 to June 30.

- What are the principal constraints to the development of effective maintenance and how can they best be overcome?

As for Bank policies with regard to maintenance, the paper attempts to answer questions such as:

- Is maintenance an appropriate object of Bank financing and, if so, what parts of it?
- Is there an internal contradiction between the Bank's readiness to finance maintenance operations and the covenants generally included in road construction loans whereby governments agree to maintain the roads?
- Are the high economic rates of return typical on maintenance projects conceptually comparable with the economic rates of return calculated for road construction projects?
- How can maintenance covenants be made more effective?

Chapter 1: The Significance of Maintenance

Maintenance of roads has three principal purposes: it prolongs road life and postpones the day when renewal will be required; it reduces the cost of operating vehicles on roads; and—especially in the form of emergency operations, such as removal of debris from landslides and repair of washouts—it helps to keep roads open and enables greater regularity, punctuality, and safety of road transport services. The first purpose corresponds most directly to the interest of the highway authority, the second to that of the operators of vehicles, and the third, more generally, to that of the inhabitants of the area traversed by the road.

Even with proper adherence to standards of construction and materials, roads deteriorate with the passage of time. The rate of deterioration may vary widely depending on the climate, the strength of the pavement and underlying subgrade, and the traffic volume and axle weights. The wear and tear of road surfaces by traffic is aggravated by rainwater and by changes in temperature. Cracking occurs in bituminous pavements, which, together with the ingress of rainwater, causes ruts and potholes to form rapidly. The bitumen in the wearing course gradually loses its binding quality, and the pavement becomes brittle. Under the effect of traffic and water, joints in concrete roads become subject to "pumping," leading to cracking of edges, spalling, and slab disfigurement. Heavy rainfalls cause ruts and washouts in earth and gravel roads, and excessive water in the upper layers reduces their loadbearing capacity, causing deformations. In dry climates, evaporation of water reduces the bond in the structure of the surface grain, which then disintegrates under traffic, so that the fine binding material is lost in dust, leaving only loose gravel. Rains may cause damage to shoulders, and unchecked vegetation may overgrow shoulders and the road itself, preventing runoff and evaporation of water. Drains and culverts need clearing, steel bridges need painting, and signals have to be kept in order. Roads have to be built, therefore, to standards commensurate with climatic conditions and expected traffic, and they must then be adequately maintained to prevent their deterioration.

Intensive analysis and data collected during the last ten years suggest that the largest benefits of highway maintenance actually accrue not to the highway authority, but rather to road users in the form of savings in vehicle operating costs. These savings are most often the dominant factor in reaching economically optimal choices of highway maintenance policy. In the case of an old or weakened pavement, for example, preservation could be adequately accomplished by recurrent patching and periodic resealing, with substantial benefit in the form of postponement of the need for full rehabilitation of the road. But, when all purposes are taken into account and evaluated together, the best solution may often turn out to be an early asphalt overlay, mainly because of the reduction in vehicle operating costs that it will bring.

Empirical analysis has shown that a paved road surface in reasonably good condition can so save on wear and maintenance of vehicles and tires as to cause total vehicle operating costs to be some 15 percent lower than they would be if the surface were being poorly maintained.[1] At today's prices, a 15 percent saving translates into a saving of about two cents a kilometer for cars and ten cents to fifteen cents a kilometer for heavy vehicles (excluding savings in the time of passengers) or an annual total of as much as $5,000 a kilometer. For roads generating traffic at a rate of 250 vehicles daily, annual savings could be as much as $5,000 a kilometer; for roads with daily traffic of 750 vehicles, total savings could be $15,000 a kilometer. For gravel roads, the saving per vehicle can be about three times this amount, but, of course, the number of vehicles will normally be much smaller.

Road maintenance comprises several small-scale engineering operations that are repeated at varying intervals, depending on climate, terrain, traffic, and design standards of the road. These operations are normally classified according to the frequency with which they are repeated. First, *routine*, or recurrent, maintenance consists of operations that normally need to be repeated one or more times every year—for example, control of vegetation, cleaning of ditches and culverts, repairs to shoulders, upgrading of unpaved surfaces, filling of potholes, patching of cracks, and emergency operations. Second, *periodic* maintenance covers operations that typically need to be repeated only every five to ten years, such as regraveling of gravel roads and bituminous surface dressings or resealing paved roads. A third group of activities, the maintenance of the *maintenance equipment and facilities*, is an essential support function that is typically incorporated within the highway organization.

The annual costs of desirable routine maintenance for paved and gravel roads in developing countries (assuming reasonably efficient operations and including equipment charges) normally ranges between about $200 and $1,000 a kilometer as a networkwide average, while the periodic work (regraveling or resealing) is about $8,000-$10,000 a kilometer in the years when it is required. For earth roads, desirable annual expenditures on the same basis are between about $100 and $1,000 a kilometer. The ranges are very wide because much depends on how extreme the climate is—especially with regard to

[1]Depending on composition and age of the fleet of vehicles and the degree of deterioration of the road network, the savings may vary from about 8 percent or 10 percent to as much as 40 percent; the 15 percent cited is somewhat conservative.

rainfall and freezing temperatures—how old the pavements are, and how heavy the traffic is.

Combining the characteristics of both maintenance and new construction is a fourth category of operation, upgrading or betterment—asphalt overlays, for example, other strengthening and rehabilitation measures, minor drainage, and improvements of alignment. These measures substitute for, or reduce, routine and periodic maintenance requirements, but they also exchange the value of service and extend the life of the existing asset to such a degree as to constitute, in substantial part, capital renewal and improvement. Obviously their cost is highly variable, depending on the extent of the work involved, but reasonable indicative figures for the major operations are $50,000-$75,000 a kilometer for an overlay and $120,000-$200,000 a kilometer for the full rehabilitation of a two-lane paved road.

Without any allowance for items in the last, fourth, category, which are generally treated as part of the capital budget, these figures imply that total annual maintenance expenditures (the sum of routine and periodic maintenance costs) need be no more than about 0.5 percent to 1.0 percent of replacement (or updated original investment) value for paved roads and 1.0 percent to 3.0 percent for gravel roads. On a networkwide basis they would work out, for example, to about 1.7 percent of total paved and gravel road capital stock in Bolivia (roughly estimated replacement value: $1,500 million) and 1.8 percent in Chad (approximate replacement value: $150 million). The corresponding benefits would normally be from five to ten times that much, with savings in vehicle operating costs 60 percent to 85 percent of the total and the savings from postponement of the need for renewal the remainder.

Small though these expenditures are in relation to the road capital stock and to the benefits that they yield, they do have to be made in a regular and timely fashion if their full potential value is to be realized. This need is so because of the significance of the savings in vehicle operating costs each year and because of the larger, additional investments that must be made earlier than planned if maintenance is neglected. Thus, if the amounts already given for routine and periodic maintenance that amount to a combined annual average for a network of about $1,500 to $3,000 a kilometer are spent regularly and effectively, not only will savings in vehicle operating costs be realized, but the need for rehabilitation or overlays can be postponed for at least several years as well.[2] Moreover, especially in the case of weaker paved roads, the ultimate expenditure for rehabilitation can be considerably less.

For unpaved roads, the empirical data gathered by the Bank deeply underline the high value of regular routine operations to maintain a

[2]For a paved road, the savings in capital and interest costs, at 12 percent, for just five years' additional life would be about $50,000 a kilometer if asphalt overlays could be used, or more than $150,000 a kilometer if more extensive rehabilitation were required.

reasonable minimum riding surface on roads with even as few as ten vehicles a day. They also show that, even for much higher volumes of traffic, the economic profitability of this work, largely grading, can greatly exceed that of regraveling. At a more detailed operational level, where the same principles of timeliness still apply, grading can be several times as effective if done immediately following the rainy season, when there is still moisture in the upper layers, rather than a few weeks later.

Timeliness is most critical of all in protection of paved roads from penetration by water. Pavement structures can be destroyed in a single season when weakened by water penetration—penetration caused usually by cracks that have not been sealed or ditches and culverts that have not been regularly maintained to ensure prompt runoff of rainfall. Normally there is a critical phase in the life of a road pavement—it may be just one or two years' duration in a wet climate—when it is essential to strengthen pavement; delay beyond this period will necessitate far more costly measures. One unfortunate illustration in the Bank's experience is the case of a road that was to have been rehabilitated a few years ago in a West African country; deterioration during the one-year delay in the award of contracts was sufficient that full reconstruction of the road was eventually required at a cost of $6 million, more than a third higher than for its rehabilitation; an additional $5 million to $6 million could probably have been saved if, two or three years earlier, a pavement overlay had been applied instead. Thus, contrary to views commonly held outside engineering circles, there are few maintenance tasks—grass cutting being perhaps the principal one—that can be reduced or postponed without engendering large penalties in future maintenance and reconstruction costs or vehicle operating costs.

Maintenance and construction really need to be seen as interacting strategies over time, for the more of one that is done on any given section of road, the less is needed of the other. Evidence indicates that, except where graveling is unusually expensive (say, more than $10 a meter laid), it is generally worthwhile initially to gravel roads when they reach traffic volumes of 15 to 40 vehicles a day. As the volume of traffic increases, a point will be reached, normally between 200 and 500 vehicles a day, at which paving is warranted. At such traffic levels, the maintenance costs for the unpaved road may be two to four times as much as they would be for a paved road with the same volumes of traffic, and vehicle operating costs will be substantially higher than on a paved road.

But how heavy should the pavement be? Research so far has suggested that, in theory, the best approach (minimum present worth of total costs) for a road with growing traffic is to lay relatively low-cost pavement initially, then to overlay the road rather frequently. Research has also shown, however, that this approach, which requires careful management and timely maintenance interventions, is, in the long run, only slightly less expensive than a somewhat heavier initial investment that provides for a stronger pavement. Without careful management, the first-mentioned approach easily turns out to be far more costly, and leads to the need for early rehabilitation or reconstruction. Thus the potentially most economical time-staging strategies, with initial low-cost pavements, appear to be a poor choice unless there is a relatively high probability that timely maintenance will be done. Economies on those aspects of design that do not concern the pavement can therefore be of great importance in helping to release construction funds for stronger pavements. Even the strongest pavements, however, still require significant amounts of maintenance, particularly to ensure proper drainage.

Tight constraints on overall highway budgets pose dilemmas in many countries and tend to give increasing importance to maintenance and maintenance-related works. In some countries, neglect of maintenance in the past means that the most crucial works in the construction category are, in fact, those of rehabilitation to restore roads to the state at which they can be preserved by regular maintenance. In others, especially those where major additions were made to the paved network in the 1960s and early 1970s, careful maintenance and timely overlays are of the highest priority if large requirements in the near future for premature rehabilitation are to be avoided. In still other countries with low volumes of traffic over extensive networks, major upgrading cannot yet be economically justified, and existing roads must be preserved. All these factors are causing policymakers to adopt a highly selective attitude toward new construction in many countries; many highway programs now concentrate mainly on spot improvements that yield quick returns and on increases in road capacity over short sections.

When roads do deteriorate more rapidly than expected, as has sometimes happened in Bank-assisted construction programs, it is often hard to tell which of many were the determining factors: excessively conservative traffic forecasts, underdesign, faulty construction (and inadequate supervision of construction), overloading of trucks, or lack of maintenance. Generally, some combination of such factors is involved, for timely maintenance interventions could, in many instances, have largely compensated for small shortfalls in the other dimensions.

A particularly serious factor often appears to have been the overloading of trucks. With any given configuration of truck axles, weight concentrated on one truck does much greater damage to pavements than the same weight divided over two and has effects similar to a much greater-than-proportionate increase in traffic. Thus, a load 50 percent above design would be equivalent in its effect on the pavement to about five trucks of design load, while a load twice the design would be equivalent to about twenty such trucks. Similarly, a truck with a single rear axle would cause a serious overload to a pavement if it were carrying a load equivalent to the design load for a truck with a tandem rear axle; a similar argument applies to single tires vs. dual tires. Traffic surveys have often revealed overloading to be extensively practiced, especially on main roads, in developing countries. Reviews of Bank-assisted projects have sometimes suggested that more attention should have been given, at the time the pavement was originally designed, to the possibility that overloading would occur, especially given the great difficulties that have been encountered in the enforcement of load limits.

The broader issue of appropriate limits on axle loads for a country requires careful economic study of the particular country in question, of what costs of strengthening and maintaining bridges and roads would, in fact, be required with various road regimes of alternative axle load limits, and of what savings in truck operating costs would be gained with the higher limits. In comparing costs to the road authorities with savings to the road users, the higher cost to the government of control and of enforcement of the tighter limits must also be taken into account. Control over production and over the types of trucks that are imported can be as important a means of overcoming the problem of overloading as weight control on the roads.

Some broad indicative ranges for appropriate levels of maintenance expenditure were cited earlier; the key, practical question, however, is how to establish what an adequate level for a particular country might be. Programs need to be designed with the distribution and growth of traffic taken into account, as well as the state of the roads and their surfaces, and the contribution that can be made by each type of maintenance operation. In formulating such a program, it is essential that the economic costs of each type of operation be minimized—for example, by emphasizing efficiently run, labor-intensive techniques where unskilled labor is plentiful. In addition, the best combination of maintenance operations should be found, one in which, in principle, each of various factors is carried to the point where it yields a marginal return equal to the opportunity cost of capital.

While the return on efficiently executed, basic, routine maintenance, such as cleaning culverts, ditches, and drains, filling potholes, and controlling vegetation is not normally in doubt, questions do arise, in the case of unpaved roads, about how often routine grading and periodic regraveling should take place. Analysis has indicated, for example, that when grading is infrequent (one grading for each 15,000 vehicle passes—that is, one grading every three to four months for a road with a medium-high traffic rate of 150 vehicles a day), the return on additional gradings is very high. As they increase, however, there is a broad range—one grading for each 4,000 to 10,000 vehicle passes—over which the returns on additional gradings are a relatively constant 10 percent to 15 percent. For a given volume of traffic, somewhat greater frequencies normally are economically justified for earth roads.

The key factors that determine the return on regraveling are its cost, the composition and growth of the traffic on the roads, vehicle operating costs (with and without graveling), and the social and economic costs of any temporary road closures that may occur in the rainy season as a consequence of the road not having been regraveled. The higher the cost of regraveling, the higher the minimum level of traffic required to warrant regraveling will be. Programming maintenance for paved roads means preparing a specially designed combination of patching, resealing, overlaying, and rehabilitation through the years for each section.

It is essential that a country's maintenance program be designed to exclude components that have a low priority and where low returns are often concealed within the overall program. There is much to be said, therefore, for approaching programming with the objective of establishing what amounts of which operations would be sacrificed in the event of, say, a 20 percent reduction in annual appropriations for maintenance operations, what would be added with a 20 percent increase, and what the returns on these decremental and incremental expenditures would be.

An inherent difficulty of maintenance planning—and an additional obstacle to presentation of a convincing case for securing appropriations by a finance ministry for maintenance—is finding a practical measurement of the parameters involved. The economic importance of maintenance can be determined by finding the interrelated small differences in the state of the roads and the costs of operating vehicles on them. The research undertaken by the Bank is based largely on extensive surveys of road roughness, the difference that changes in roughness make in vehicle operating costs, and the costs of maintenance operations restoring road roughness to a lower level or stabilizing roughness at current levels.[3] A few developing countries—Bolivia, Brazil, India, Kenya, and Tunisia for example—have obtained instruments for measuring the roughness of a road. But the science of measuring degrees of roughness is still at an early stage of development and is not universally known. Many developing countries are undertaking deflection surveys on paved roads.[4] These surveys have not yet been conducted, however, on the regular annual basis that may be necessary if rates of deterioration are to show up; it is difficult, therefore, to establish to a sufficiently precise degree when and how thorough a strengthening is required. These measuring devices, moreover, deal only with part of what is involved in maintenance.

Experienced judgment is inevitably required if values of the parameters that enter into the preparation and assessment of maintenance programs are to be established. Progress in these instances in which more scientific methods are applied helps to generate benchmarks and relationships for improving the application of judgment in other, similar cases. Visual impression and roughness "feel," nonetheless, will remain important primary indicators of the state of roads and of what various maintenance operations can do about it. This is true in many developing countries as well as in most

[3]Road roughness, as indicated by the cumulative recording of the response of a vehicle to surface irregularities over a certain length of road gives a measure of the quality of the road surface. While a certain amount of roughness is built in at construction, it generally increases with the pounding of traffic and with climatic effects.

[4]Pavement deflection, as measured under specified loads, indicates the structural strength of the pavement layer system. As the pavement is weakened through the action of traffic, ingress of water, and so forth, the deflection increases.