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Road Deterioration in Developing Countries

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ROAD DETERIORATION IN DEVELOPING COUNTRIES

TABLE OF CONTENTS

Road Deterioration in Developing Countries was prepared under the direction of Louis Y. Pouliquen, Director, Infrastructure and Urban Development Department. The main contributors to the report were Clell Harral, Asif Faiz, Graham Smith, and Anil Bhandari. Esra Bennathan provided useful counsel throughout and assisted in drafting various versions of the report. Per Fossberg and William Paterson provided help on technical and engineering issues and Edward Holland in drafting the report. The guidance and comments given by S. Shahid Husain, Parvez Hasan, Curt Carnemark and Sir Alan Walters are gratefully acknowledged. Thanks go to regional transport staff who reviewed the report at various stages, to Meta de Coquereaumont and Bruce Ross-Larson for editing, to Rodrigo Archondo-Callao and Olivier Bottrie for research assistance, and to Mari Dhokai and Marjeana Gutrick for typing.

Glossary of Key Terms

Road Conditions

GOOD Paved roads substantially free of defects and requiring only routine maintenance. Unpaved roads needing only routine grading and spot repairs.

FAIR Paved roads having significant defects and requiring resurfacing or strengthening. Unpaved roads needing reshaping or resurfacing (regraveling) and spot repair of drainage.

POOR Paved roads with extensive defects and requiring immediate rehabilitation or reconstruction. Unpaved roads needing reconstruction and major drainage works.

Road Maintenance and Improvement Works

ROUTINE MAINTENANCE Local repair of roadway and pavement; grading of unpaved surfaces and shoulders; regular maintenance of road drainage, side slopes, verges, traffic control devices, and furniture; roadside cleaning, dust and vegetation control, snow or sand removal, and maintaining rest areas and safety appurtenances.

RESURFACING Resealing a paved road or regraveling an unpaved road to preserve its structural integrity and ride quality.

REHABILITATION Selective repair, strengthening and shape correction of pavement or roadway (including minor drainage improvements) to restore structural strength and ride quality.

RECONSTRUCTION Renewing the road structure, generally using existing earthworks and road alignments, to remedy the consequences of prolonged neglect or where rehabilitation is no longer possible.

RESTORATION Major rehabilitation and reconstruction works considered together.

BETTERMENT Road improvements related to the width, alignment, curvature, or gradient of road (including associated resurfacing and rehabilitation works) to improve traffic speed, safety, or capacity.

NEW CONSTRUCTION Constructing a paved, gravel, or earth road on a new alignment; upgrading a gravel or earth road to paved standard; providing additional lane capacity; or constructing additional carriageways, frontage roads, grade-separated interchanges, or multilane divided highways.

ROAD DETERIORATION IN DEVELOPING COUNTRIES

Executive Summary

i. The developing countries have lost precious infrastructure worth billions of dollars through the deterioration of their roads. If they do not immediately begin to do much more to preserve their roads, they will lose billions more. Large road networks, built at great expense, have been under-maintained and more heavily used and abused than expected. If this neglect continues, the deterioration of roads will accelerate as old pavements crumble and new ones outlive a fairly long period when the effects of neglect are barely perceptible.

ii. The cost of restoring these deteriorated roads is going to be three to five times greater than the bill would have been for timely maintenance. And restoration is only part of the cost. Vehicle operating costs rapidly outpace the costs of road repair as the condition of roads passes from good to fair to poor. Together, these avoidable costs are going to be a heavy drag on further economic development.

The Repair Bill for the Next 10 Years: $90 Billion or much more?

iii. In the 85 countries that have received World Bank loans for roads, a quarter of the paved roads outside urban areas need reconstruction -- as do a third of the unpaved roads. This work will cost $40 to $45 billion. (Earlier preventive measures costing less than $12 billion could have saved these roads and held down the operating costs for road users.)

iv. In addition, another 40 percent of the paved roads in these countries require strengthening today or in the next few years. This work, along with routine maintenance, will cost another $40 to $45 billion over the next ten years. That brings the total bill for these countries to about $90 billion. But if these countries do not improve their management of roads, the eventual cost of restoration could easily increase two-to-three fold. And the cost to users would rise even more.

What Caused the Deterioration?

v. In the 1960s and 1970s, road networks expanded much faster than the corresponding maintenance budgets and institutional capacities. Traffic has also become much heavier than expected, and axle loadings have often exceeded the designed capacity of pavements. These patterns are evident almost everywhere. Less evident is what has been happening to the roads.

vi. New paved roads, if inadequately maintained, deteriorate slowly and almost imperceptibly during their first 10 to 15 years, depending on the traffic. After that grace period, the pavements deteriorate much more rapidly. Without timely maintenance, they break apart.

vii. As roads become rougher, the costs of operating vehicles -- and of transporting goods -- begin to shoot up. The neglect of maintenance continues, however, because it is the vehicle operators that pay these costs -- and pass them on. Road authorities are sheltered from these costs. Nor do road authorities come under immediate pressure to improve road conditions. Road users are often slow to see the link between road conditions and the prices of goods and transport services -- and even slower to try to do something about it.

viii. In the absence of public pressure and a clearer understanding of the seriousness of the problem, few governments have given road maintenance a high priority in their budgetary allocations. The urgency of the situation has not always been fully appreciated by all donors and lending agencies, some having been readier to provide funds for new construction than for maintenance. New construction has sharp political visibility, maintenance little glamour. Inadequate maintenance in developing countries has various causes, but institutional failure is the only explanation for its wide extent. At the heart of this failure is the absence of public accountability.

The Requirements for Efficient Restoration

ix. The task now facing many developing countries -- as well as the Bank and other aid agencies -- is to salvage roads that have deteriorated severely and to protect newer roads from a similar fate. This task has major financial, technical, and institutional requirements. Of these, the institutional requirements are the most pressing.

x. The technical options today seem richer. Thanks to advances in understanding the physical process of road deterioration, there now are ways to keep roads serviceable at lower cost than before. The financial requirements of road deterioration, on the other hand, are large. Some countries will require large infusions of external capital; all will need political resolve to mobilize resources at home. But additional financial resources will not by themselves assure effective restoration and preservation of roads. Nor will they prevent a recurrence of the kind of crisis and waste so evident today. Needed above all is a reform of the institutional base of the road sector. Accountability must be stronger in all entities and activities that maintain public assets. Public and political attention must be deliberately fostered. The organization, manning, and activities of the institutions looking after roads must be improved to increase their absorptive capacity.

xi. Technical requirements. Standard engineering practices have very different effects in different environments. Road investment and maintenance strategies must therefore be tailored to the circumstances of individual countries. The growing understanding of road deterioration nevertheless offers some general guidance.

xii. For one thing, the savings in vehicle operating costs from paving lightly traveled roads are less than previously estimated. And the total life-cycle transport costs on paved and unpaved roads are nearly the same over a wide range of traffic volumes (typically 150 - 400 vehicles a day) — so long as the roads are reasonably maintained. Big differences in cost arise only if maintenance is not done or deferred. If the availability of funds for future upkeep of paved roads is uncertain, it is economically safer to keep lightly traveled roads unpaved and reasonably maintained.

xiii. It also makes sense — in times of budgetary stringency when road allocations are not too far below the optimum — to consider alternative maintenance strategies. Some strategies involving small cuts in spending barely affect the costs to users. Others, while similar in amount, can drive user costs up substantially. Still other strategies, involving much deeper cuts, can multiply the future cost to both the road agency and the user — so much that they are self-destructive. For example, if the budget cuts are so large that they preclude the resurfacing or strengthening of paved roads now in fair condition, these roads will soon fail structurally and require much more costly restoration. This, regrettably, is the situation in many developing countries, and it will soon spread to many more.

xiv. Here are some of the technical choices that each country should examine in light of its needs and capabilities:

- Gravel roads should be paved only after a complete analysis of the costs, climate, present and future traffic, and reliability of future maintenance.

- If the volume of traffic indicates paving, the strength of the pavements should be guided by the likelihood of undermaintenance and excessive axle loads. If that likelihood is high, pavements should be built to the required strength immediately rather than in stages.

- Deterioration of paved roads is gradual and barely perceptible during a long initial phase that lasts up to two-thirds of the pavement life cycle. Resurfacing and strengthening can thus be deferred somewhat — so long as the roads remain in fair condition and have not entered the final critical phase of their life cycle. Longer deferral will cause pavements to break up. The stage of a paved road in its life cycle must therefore determine the decision to defer resurfacing and strengthening operations.

- Traffic is critical for maintenance decisions. If funds are tight, it may be best to keep heavily traveled roads in fair or good condition and to reduce substantially the maintenance of roads with light traffic. Even if funds are not tight, it may make little economic sense to fully restore paved roads that are lightly traveled. And if funds are very tight, it may be best to let lightly traveled roads deteriorate further, applying only low-cost patching to keep them usable.

xv. <u>Institutional requirements</u>. The inadequacies of road maintenance stem in part from the structure and functions of the traditional road agency. Often a public monopoly, the agency has too many responsibilities — for planning, controlling, and executing both construction and maintenance. And the agency typically devotes too many staff, funds, and facilities to execution — to the detriment of planning, control, and evaluation. It listens only to itself. That makes it desirable in many countries to separate the execution from the other functions, lodging it in a separate government agency or in the private sector. Where this separation has succeeded, the incentives for good performance have been strong, and the delineation of accountability has been clear.

xvi. A road agency also needs an effective management information system to monitor traffic, road conditions, and (just as important) its internal workings. The agency should be equipped to analyze the life-cycle costs of construction and maintenance and present and future cost to users. Testing alternative design and maintenance policies for their sensitivity to different discount rates, traffic loads, and other variables will be difficult without a specially designed computer model. Without a reliable data base and capable staff, it will be impossible.

xvii. The road agency should, above all, introduce mechanisms to increase the accountability for performance and for resource use — and to provide incentives for good performance in the agency and by the contractors it engages. It should, moreover, work with the media and with nongovernmental organizations to make the political leadership and the public aware of the effects and high costs of failing to maintain the roads.

xviii. <u>Financial requirements</u>. The present bill for repair and maintenance is about $90 billion, or $9 billion a year for the next 10 years. That could arrest future deterioration and clear up the backlog of economically warranted restoration. If the work were finished in five years, however, the costs would come down to less than $70 billion — or about $13.5 billion a year. (Road spending in 1984 was about $13 billion, but only a half went for restoration and maintenance.)

xix. These aggregate sums obscure wide differences from country to country. The 61 developing countries having data on road spending fall into three categories of capability — with about a third in each. First are the countries that could meet future maintenance requirements and eliminate their backlogs in five years with no increase in their total spending on roads — but only by holding back on new construction and allocating up to 80 percent of that total to restoration and maintenance. Next are the countries that could do the same in 10 years — but only by raising their spending for those years by 50 percent and by allocating 80 percent of that total to restoration and maintenance. Last are the countries that would have at least to double their spending — even if they devote all of it to restoration and maintenance.

xx. To justify more spending on roads and its reallocation to restoration and maintenance, each country will have to perform a systematic analysis to determine how much should be spent on roads — and how. Some countries may choose to revise user charges or impose new ones, which if translated into better roads can reduce rather than increase vehicle operating costs. Some may decide that to avoid misallocations they will have to earmark budgeted funds for restoration and maintenance, especially the funds that might be raised through a temporary surcharge. And some will have to rely heavily on external sources of finance.

Implications for the Bank

xxi. Economic losses - actual or potential - resulting from inadequate road maintenance can have important implications for the Bank's macroeconomic dialogue with its borrowers, particularly in the context of public expenditure priorities. The evidence in this paper suggests that in a number of countries the economic returns from expanded expenditures on road maintenance would justify a substantial expansion of such outlays relative to expenditure on new road construction. It is also quite possible than an expansion in total expenditures on roads relative to other sectors would be warranted in some countries. That determination, however, can be made only by a comprehensive review of public expenditures which evaluates the comparative benefits of proposed outlays in all major sectors.

xxii. The developing countries differ according to their need to expand and improve their road maintenance organizations and procedures, their need to increase their total road budgets and make reallocations from construction to maintenance, and their need for external assistance. In addition, some have obsolete networks, others new ones. These differences suggest several distinct categories of need for external assistance in the roads sector. The Bank's lending for roads should be tailored to the circumstances in each category — and be conditional on an acceptable distribution of road expenditures for maintenance, restoration, and new construction.

- For countries with the best performance (Category I in the text) — largely, but not exclusively upper middle-income countries — the Bank will view itself mainly as a vehicle for institutional and technological improvements. It will nevertheless extend funds for balanced programs of maintenance and new construction.

- For countries where road maintenance is inadequately funded (Category II) — including a substantial number of middle-income countries — the Bank will provide external finance mainly for maintenance and restoration. Such finance will be linked to policy and institutional reforms.

- For countries with severe financial and institutional constraints on maintenance (Category III) — almost exclusively low-income countries — the Bank's assistance over the next few years will be devoted with few exceptions, to maintenance and restoration. The assistance will be conditional on institutional reforms and on the allocation of road budgets exclusively to maintenance and restoration (with only limited and defined exceptions).

- For countries with obsolete roads, technology, and organization (Category IV), the Bank will emphasize organizational and technological improvements in modernizing the road networks and will also support new construction when it is justified.

In all this, the Bank will encourage the execution of maintenance work by entities outside the road authority — entities operating on commercial principles, preferably in a competitive environment. In addition, the Bank will promote measures to educate officials and increase public awareness of the need for timely maintenance and the high cost of neglecting roads.

xxiii. The Bank will also promote more coordinated action by the international community in dealing with the growing problem of road deterioration in the developing countries. To this end, the Bank will work closely with other aid agencies in designing road programs appropriate to the needs of each country (along the lines of the four categories just spelled out). The Bank will also work closely with other aid agencies in supporting research on roads — work that would be done mainly by road agencies and road research institutions in the developing countries. The emphasis in these efforts will be on international exchanges of data, technology, and management information systems. The Bank will support compilation and publication of statistics on roads — work that should be undertaken by the United Nations Statistical Office or an organization such as the Permanent International Association of Road Congresses or the International Road Federation. External agencies should provide financial assistance for this effort.

xxiv. The recommendations for World Bank policy emerge from a view of the root causes of road deterioration in countries where it is now severe. We know now that some past investments have been mistaken. We know, too, that deterioration reveals its symptoms late and gives little warning of what is to come. Added to these factors are the civic calamity in some countries and the harsh and prolonged economic adversity in many more. But where the road problem is now serious or is about to turn serious, the damage attributable to such other factors could usually have been contained by more effective, responsible, and attentive institutions — by more efficient institutional arrangements for the management of the country's infrastructure. It is difficult to understand fully the causes of institutional failure in different countries — even more difficult to prescribe countermeasures guaranteed to cure the problem. But this is no case for leaving things as they are. Action is required, even if it has to be accepted as experimentation. Bank support for the road sector of countries with serious road deterioration problems will therefore be guided by signs of institutional progress. These signs include the growth of political attention to the preservation of infrastructure, the strengthening of accountability in the institutions charged with managing it, the introduction of incentives that press people to perform, and the deliberate search for resources and schemes that promise care for hard-won national assets.

CHAPTER 1: THE STATE OF THE ROADS

1.01 The developing world's road building boom in the 1960s and 1970s created an infrastructure that has been crumbling in the 1980s. If not quickly strengthened and protected, this crumbling infrastructure threatens to collapse in the 1990s. Large road networks, built at great expense, have been inadequately maintained and used more heavily than expected. The result in many developing countries is a network of deteriorating roads. Many roads are in such poor condition that normal maintenance is no longer sufficient or effective. These roads now require rehabilitation or reconstruction at three to five times the cost of timely preventive maintenance and strengthening (see the glossary of terms). And many more roads, whose deterioration is not yet visible, will soon reach that point without substantial improvements in maintenance and rehabilitation.

.02 The problems of poor maintenance are worse for roads than for other sectors for three reasons:

- The costs and financial requirements are very large. For example, expenditures to compensate for past omissions in preventive maintenance in Sub-Saharan Africa are at least 10 times those of supplying textbooks for all elementary school children in the region until the year 2000.

- Road deterioration accelerates with time. This phenomenon makes it difficult, but also all the more important, to recognize the need for preventive maintenance before deterioration becomes obvious and more expensive rehabilitation or reconstruction becomes necessary.

- Road authorities are insulated from the effects of undermaintenance. The agency responsible for road maintenance usually is not exposed to either the economic consequences of undermaintenance or

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This report assesses road deterioration in the 85 developing countries receiving highway sector assistance from the World Bank Group. [11] The analysis covers only the main road networks, both because they are the most important and valuable roads and because information on other roads is too fragmentary. In these countries, 70 to 80 percent of interurban traffic is on the main networks. These networks consist of 1.8 million km of primary and secondary roads, of which 1.0 million km are paved, and have a replacement value of about $300 billion, excluding the value of land, bridges, and major earthworks (See Statistical Table A). The main networks generally include the principal roads and highways crossing urban areas or providing access to ports. The analysis does not deal with urban roads; nor does it cover 5 to 6 million kilometers of local rural roads and tracks (mostly unpaved and with low traffic volumes), with a replacement value of perhaps $75-$100 billion.

the organized pressure for better roads, and the urge to provide responsive, effective maintenance is thus weakened.

1.03 The costs to road authorities are only the tip of the iceberg, for the costs to road users operating vehicles on rough roads are much larger. These high and rising road haulage costs constrain the location of economic activity, hamper the integration of economic markets, limit the gains from specialization, and render unviable many activities that rely on transport (See Box 1.1).

An Overview of Road Conditions

1.04 Detailed assessments of road conditions at present are subject to considerable error. The importance of systematic monitoring and evaluation of road conditions has only recently become generally recognized. Furthermore few developing countries have technically adequate data bases and management information systems. Nevertheless, the evidence is good enough to show the broad dimensions of the problem. Recent field surveys supplemented by the judgment of World Bank engineers, permit the broad categorization of the distribution of a country's roads among three classes of condition: good, fair, and poor. [23, 24] A road in "good" condition requires only routine maintenance to remain that way. A road in "fair" condition needs resurfacing. A road in "poor" condition has deteriorated to the point that it requires either partial or full reconstruction (See Glossary for a definition of road maintenance and improvement works).

1.05 Three facts about road deterioration help to clarify the problem. First, because reconstruction costs three to five times as much as resurfacing or rehabilitation, no road should be allowed to decline into poor condition unless it is to be kept deliberately in that condition (with routine maintenance but no resurfacing or rehabilitation) or abandoned entirely. Second, paved roads in fair condition normally have a window of opportunity of about five to eight years when they can be restored by resurfacing or strengthening. The existence of many roads in fair condition suggests, therefore, that extensive maintenance is needed quickly if these roads are to be saved before they reach poor condition. And third, the cost of operating vehicles (especially larger trucks) rises as roads deteriorate. Because vehicle operating costs are the largest part of road transport costs on all but very lightly traveled roads, the increase in operating costs swamps all other costs at stake in road management as roads deteriorate.

1.06 The road conditions in different countries combined into regional averages, are alarming on two counts (Table 1.1). First, more than a fourth of all paved roads -- some 269,000 km -- are already in poor condition and need rehabilitation or reconstruction.1/ Second, the heavy concentration

1/ Less serious deterioration in the United States (US) federal aid highway network during the 1970s prompted widespread alarm, new legislation, new user taxes, and a large infusion of federal and state resources in the 1980s to remedy the situation. [2, 40]

Box 1.1

The Consequences of Road Neglect in Ghana

Road deterioration can make an economic crisis worse. In Ghana a good road network was built before 1970, but it later suffered from serious neglect. By 1984, about 60 percent of the main paved roads were in a state of moderate to severe deterioration. Important sections have become almost impassable, and access to some interior areas has been severely curtailed. Transporters refuse to go there because they do not want their vehicles to break down.

Transport costs have increased in real terms by about 50 percent on main roads and by over 100 percent on rural roads that have suffered even greater neglect. In many areas, the market rate for transporting fertilizer is as high as a dollar per ton-mile. These high transport costs have cut deeply into farm returns, particularly for poor farmers in areas away from main roads: some villagers can no longer move their cocoa stocks to regional depots. And during the 1982-83 famine, poor roads prevented the transport of food from surplus areas to areas facing starvation. The high transport costs have also hit the timber industry. Logs moving from the Kumasi area for export through the Takoradi Port are trucked over a 500-kilometer route because the direct road, which is about half as long, is broken down and the rail services are unreliable. The detour adds US$15-20 for each ton of logs exported.

The prospects are not encouraging. Road resurfacing and strengthening covers only about 20 percent of estimated annual needs of about $47 million, mainly for resealing 1,100 km of paved roads and regraveling 1,600 km of unpaved roads. Even with a recent road maintenance project supported by the World Bank, maintenance will increase only to about 30 percent of the need by 1989. Unless more resources can be put into road maintenance -- and applied effectively -- deterioration will continue. Ultimately it will require far more costly rehabilitation, if financed, or result in an almost total collapse of road transport.

of paved roads in fair condition (42 percent) foreshadows a major crisis unless concerted efforts prevent these roads from deteriorating into poor condition.

1.07 The unpaved roads in the main networks are even worse. True, a road authority's timing of maintenance for unpaved roads is less critical than for paved roads because the costs of restoring unpaved roads are less sensitive to the timing of intervention. Even so, the aggregate effect of their deterioration on vehicle operating costs can be considerable. Although unpaved roads normally carry much less traffic, the riding condition of an unmaintained unpaved road deteriorates many times faster than that of a paved road (except in the terminal phase of the paved road's life cycle). Deferring simple routine maintenance on unpaved roads can quickly double the vehicle operating costs.

Major Determinants of Road Conditions

1.08 The considerable variation in road conditions in different countries and regions stems from differences in the past maintenance needs of individual networks and in the countries' responses to those needs.

1.09 Need for maintenance. The maintenance needs of a road network can be predicted fairly accurately from a set of structural characteristics, such as age, climate, traffic, design standards, construction quality, and subsequent maintenance. Of these, age, traffic, and construction quality are particularly important for understanding the situation in developing countries.

1.10 Age is important to the condition of paved roads because of the time-path of their deterioration. Typically, two-thirds of pavement deterioration (and an even higher proportion of maintenance cost) is concentrated in the final third of the design life of the pavement (para. 2.03). After a boom in road construction, a grace period of several years — when roads remain in good condition regardless of maintenance — is followed by a period when the need for maintenance surges dramatically.

1.11 Differences in the age of networks underlie the regional differences shown in Table 1.1. In West Africa, paved roads are on the whole in better condition than elsewhere. The networks there are fairly new: more than half the paved roads were constructed, upgraded, or reconstructed during the last 10 years. Nigeria and Cote d'Ivoire have substantially rebuilt their paved networks since 1975 (See Box 1.2). Some other countries, less well endowed, were helped by external aid agencies to develop and improve their road networks. Of 20 West African countries for which information is available, 15 have young networks. The proportion is not much lower in Eastern or Southern Africa, where 10 of 16 paved networks are fairly new. Without substantial external assistance, many of these networks are unlikely to remain serviceable beyond the next 10 years.

1.12 The growth of traffic on roads built to obsolete design and construction standards helps to explain the general road conditions in South

Table 1.1 Condition of Main Roads a/ (percentages weighted by length of country networks)

Region	Paved			Unpaved		
	Good	Fair	Poor	Good	Fair	Poor
Eastern Africa	42	32	26	42	30	28
Western Africa	52	23	25	20	36	44
East Asia	20	59	21	41	34	25
South Asia	19	45	36	6	39	55
Europe, Middle East, and North Africa	41	35	24	30	46	24
Latin America and Caribbean	44	32	24	24	43	33
Average	32	42	26	31	36	33
United States (Federal Aid Network, 1981) b/	31	57	12	-	-	-
United Kingdom (Trunk Road System, 1983) c/	85	12	3	-	-	-

a/ As reported in an internal World Bank survey of 85 countries based, as far as possible, on published pavement condition information (60 countries) and supplemented, where necessary, by the judgment of Bank highway engineers. See the glossary for definitions.

b/ After Public Works Infrastructure: Policy considerations for the 1980's, pp. 20-21. [40]

c/ Adapted from Investment in the Public Sector Built Infrastructure - Report A: Roads and Bridges, p.9. [38]

Box 1.2

Nigeria's New Roads and the Risk of Massive Deterioration

Of the 21,000 km of paved roads in the Nigerian Federal Trunk Road System, 36 percent were constructed or rehabilitated during 1975-80 and another 24 percent during 1981-85. As a result, 62 percent of the network is rated good, 15 percent fair, and 23 percent poor. Neglect of the unpaved network has resulted in an estimated 90 percent in poor condition.

Despite the remarkable expansion and improvement of the Nigerian trunk road system during the last 10 years at an estimated cost of about US$8 billion, the situation is still precarious. Many of the roads were built with generous geometric features but weak pavements, which require substantial strengthening. Without an extensive pavement resurfacing and strengthening program covering about 2,000-3,000 km a year, at an estimated annual expenditure of about $150-200 million, the Nigerian trunk road system may deteriorate rapidly, requiring massive rehabilitation and reconstruction in the next 10 to 15 years.

Asia: only 19 percent of paved roads remain in good condition, and 36 percent are in poor condition. South Asia's road networks consist mainly of aging roads with neither the geometric capacity nor the structural strength to carry current traffic. Both the volume of road traffic and the axle loads have increased there over the past decade as economies have grown and traffic has shifted from other modes. For these networks the replacement and upgrading of obsolete roads is needed beyond normal maintenance and rehabilitation. Countries in South Asia, particularly India, face the need for a very large program of road building.

1.13 The age of networks and the growth of traffic explain some differences in maintenance requirements, but the condition of the roads reflects the extent to which maintenance requirements have been met. Where maintenance has failed, it is largely an outcome of misallocated funds, unsound maintenance strategies, and inefficient implementation.

1.14 Financial capacity. The capacity to pay for road maintenance from domestic sources depends on a country's resources. Gross National Product (GNP) per capita may thus be a good index of financial capacity, although some governments are able to capture more of it than others. And of the fiscal intake, the allocation to highways is a political decision, reflecting a judgment about national priorities. Variations in income growth also affect funding: severe setbacks in income growth clearly explain some important instances of underfunded maintenance and consequent road deterioration.

1.15 Road conditions in Latin America are worsening rapidly, mirroring the general economic downturn and accompanying financial stringencies over the past five years — and illustrating how quickly roads can deteriorate once they reach the critical age. Brasil, with by far the largest road network in Latin America, has seen serious erosion despite substantial efforts. In 1984, 28 percent of the network was in poor condition, up from 18 percent in 1979 (see Box 1.3). The deterioration was even more dramatic in Honduras, which previously had adequate road maintenance. The percentage of the paved roads in good condition there dropped from 82 percent in 1981 to 50 percent in 1984, due largely to financial constraints.

1.16 A broad indicator of the economic burden of road maintenance is the ratio of a country's road network length to gross national product (GNP), with an allowance for the lower traffic volumes in poorer countries. The ratio for main roads ranges from 0.3 km per million dollars of GNP for Korea and 0.4 for Nigeria to more than 8.0 for Zaire and Botswana and 14.8 for Guinea-Bissau. Of the 36 countries with the highest ratios, 32 are in Sub-Saharan Africa (from Statistical Table B). Even with the best management, these countries face the world's highest burden of road maintenance requirements relative to income and are likely to have lower than average maintenance.

1.17 Financing road maintenance by borrowing from external commercial sources abroad or from development institutions could help to fill the funding gap, but many of these sources have preferred to finance construction rather than maintenance.

Box 1.3

A Case of Undermaintenance: Brazil's Federal Highway Network

A 1979 survey of Brazil's federal highway network showed the following distribution of road conditions:

Good	10,000 km	24%
Fair	23,000 km	58%
Poor	7,000 km	18%

Restoration and preventive maintenance of all roads at that time would have cost $1.8 billion in constant prices. A repeat survey in 1984 rated the network as follows:

Good	14,000 km	30%
Fair	19,000 km	42%
Poor	13,000 km	28%

The increase in the percentage of roads in good condition resulted from new construction not good maintenance: 6,000 km of new paved roads were constructed, while 2,000 km of those formerly in good condition declined to fair condition. Nor did the massive backlog of roads in fair condition receive the resurfacing and strengthening that was due. Some 6,000 km of that group deteriorated to poor condition, greatly increasing the number of kilometers and the percentage of roads needing rehabilitation or reconstruction rather than just preventive maintenance. The cost of this restoration is estimated at $1.7 billion, and the cost of preventive maintenance needed to save the roads still in fair condition is estimated at about $750 million. Thus the federal rehabilitation and maintenance backlog grew to $2.4 billion, a one-third increase in six years.

1.18 Institutional capacity. The foregoing indicators -- the differences in GNP per capita and its rate of change, the ratio of network length to GNP, the age distribution of roads, and the volume of traffic -- do not fully account for the variations in road conditions from country to country. Several higher-income developing countries have poor roads while some of the lowest income countries have better ones. The capacity of a country to deal with its maintenance needs also depends on how effectively and efficiently it can translate funds into protecting and rehabilitating the road infrastructure -- generally known as institutional capacity.

1.19 Institutional capacity has several facets. One is the pool of skills, such as the size of the labor force that can be applied to the activity. Others are the soundness of the maintenance strategy -- type, level, and timing of intervention -- and the managerial and operational efficiency in executing the strategy. These depend, in turn, on such factors as government commitment, institutional structure, managerial ability, staff quality, accountability, and incentives. Experience with these aspects of institutional capacity has often been remarkably disappointing. And where limited institutional capacity cannot readily be expanded, the prospects are poor for recovering infrastructure that has already deteriorated or for preventing heavy losses of capital where the peak of maintenance needs is yet to come.

The Hard Core of the Problem

1.20 Not all countries facing a maintenance crisis have arrived there by the same trajectory. Some have backlogs of maintenance needs because their financial and institutional capacities have not expanded as fast as their road networks. Some have built up backlogs by deferring needed maintenance during adverse economic conditions. And some do not appear to have backlogs now, but their networks of relatively recent construction will soon require greatly increased and systematic maintenance to prevent rapid deterioration. The road deterioration problem thus pervades the developing world. At the core of the problem are mainly the countries of Sub-Saharan Africa and South Asia. And at the hard core of the problem are Sub-Saharan African countries whose financial and institutional capacities are unequal to the task at hand or to the one they will soon have to face.

1.21 Although some networks in Sub-Saharan Africa are among the better maintained (in Cote d'Ivoire, Malawi, Niger, and Rwanda), they are also of recent vintage and will soon require much more maintenance as the paved roads pass into the critical stage. In the rest of Sub-Saharan Africa, recently expanded networks are also numerous and therefore in better condition than older ones. In 10 countries with older networks, an average of 44 percent of their paved road length is in poor condition: in the 17 countries with fairly new paved roads, the proportion of poor roads is only 22 percent. There is, however, no reason to believe that countries with newer paved networks have better capacities or policies for road maintenance than those with older networks. If they do, their unpaved roads should be in better condition -- without maintenance, unpaved roads deteriorate rapidly and at a uniform rate. The condition of unpaved roads in countries with newer paved roads differed little from that in countries with older paved roads. So, the state of a country's paved roads says little about its road maintenance capacity.

1.22 In many countries, the rapid expansion of networks has outstripped the growth in institutional capacity for road maintenance. But full consequences of this lag are not yet evident in most paved networks, because most of the roads are still in the grace period when they need little maintenance and show few signs of deterioration even when maintenance is neglected. The effects of undermaintenance are already reflected in the relatively poorer condition of unpaved roads in all regions. In Nigeria, 62 percent of the paved roads are in good condition, while none of the unpaved roads are rated as good. In Cote d'Ivoire, 78 percent of the paved roads and only 30 percent of the unpaved roads are classified as good. Both countries developed their paved networks fairly recently, so their maintenance requirements will grow significantly in the next few years. Almost every region has some countries in or approaching crisis, but Sub-Saharan Africa stands out as having the most countries at the hard core of the road deterioration problem.

CHAPTER 2: TECHNICAL OPTIONS AND ECONOMIC CONSEQUENCES

2.01 A few fundamental relationships explain road deterioration and its consequences for the total cost of road transport. They hold in a wide variety of environments and form the starting point of any rational maintenance plan. Recent research has greatly clarified these relationships and has quantified and refined them empirically, thus enabling the design of economical maintenance strategies for a wide range of circumstances. And they show that some past strategy decisions have been wrong. Above all, these relationships make it possible to provide firmer guidance for countries that have to restore badly deteriorated parts of their networks while keeping the other parts serviceable.

2.02 Economic decisions about a highway system must take into account the total cost of transport on the roads: the discounted life-cycle cost of constructing and maintaining the roads and the (usually) far larger cost of operating vehicles on these roads. The estimation of these costs, in turn, must be based on sound knowledge about road conditions, about how those conditions and the various vehicle types and operations affect each other, and about the applicability of different maintenance techniques in different environments.

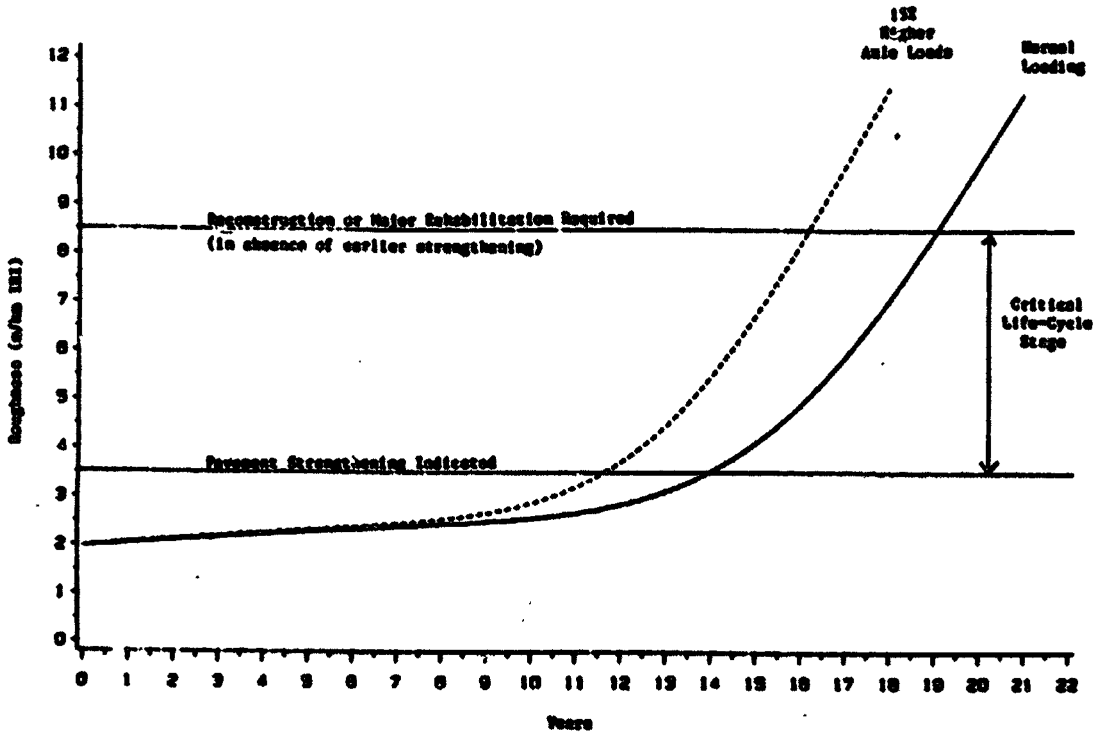
The Fundamental Relations

2.03 As roads deteriorate they get rougher. Until recently roughness was assessed subjectively; now it can be quantitatively evaluated using measures such as the International Roughness Index (IRI). [33, 34] Unpaved roads, if not maintained, deteriorate very rapidly, at a fairly uniform rate throughout their life cycle.1/ But unmaintained paved roads follow a distinctly nonlinear path (Figure 2.1). During a long initial phase that lasts up to two-thirds of their life cycle, paved roads undergo little visible deterioration. This stage is followed by a phase of increasing deterioration — slow at first but then rapidly accelerating (into fair condition) — that ends within a few years in radical structural failure (poor condition). This nonlinear deterioration affects the choice of optimal maintenance policy for paved roads. For the unwary, it also tends to disguise the future maintenance requirements of young networks.

2.04 During the first phase, maintenance needs are minimal, and a paved road can be kept in good condition by fairly inexpensive routine maintenance.

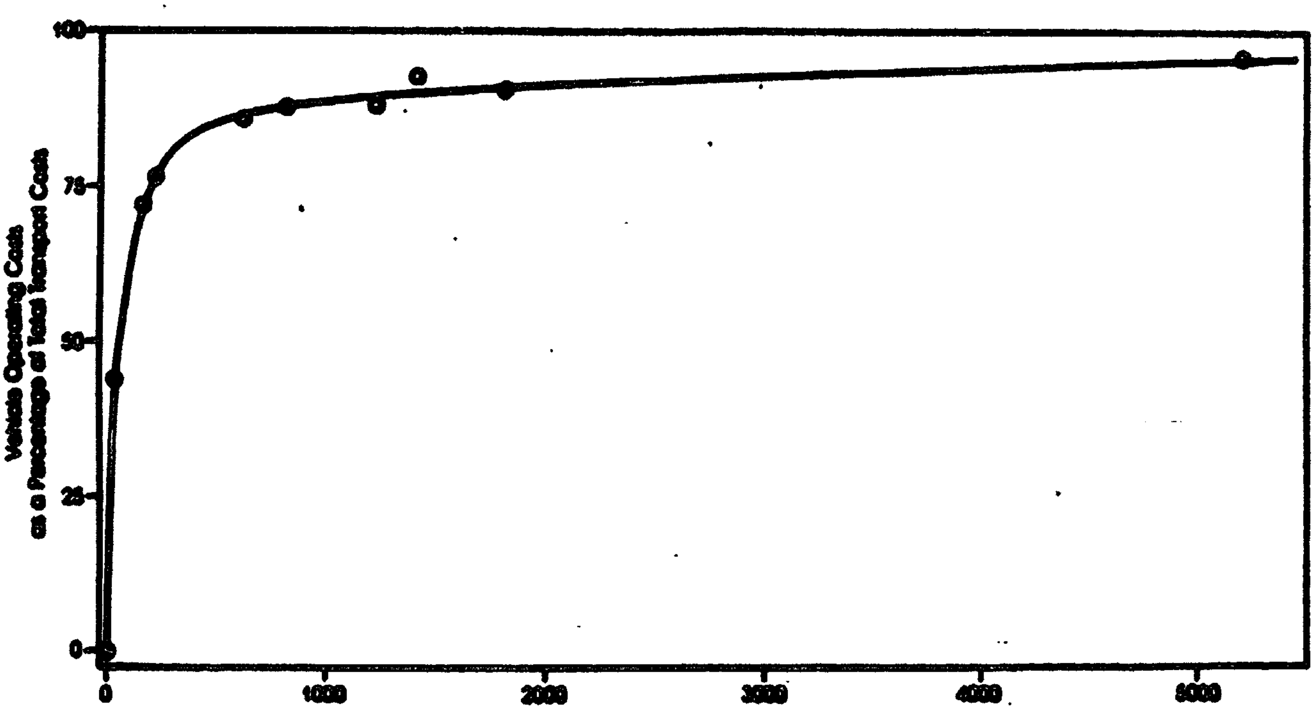
1/ All references to the absence of maintenance assume that the minimal work of vegetation control and clearing drainage is still carried on. These activities, which are very low in cost, are vital to the continuing serviceability of roads, and neglecting them is a sure way to hasten road deterioration.

Figure 2.1 Road Deterioration Over Time



Assumptions: Asphalt Concrete Pavement, (Structural Number = 3.5)
Traffic = 2300 vehicles per day
Rainfall = 120 mm/month
Minimal Maintenance

Figure 2.2 Vehicle Operating Costs as a Percentage of Total Life-Cycle Transport Costs for Typical Cases with Optimal Maintenance



Initial Average Daily Traffic (3% annual traffic growth rate)

Note: Present values discounted at 12 percent a year for construction + maintenance + vehicle operating cost.

In the subsequent phase of increasing deterioration (into fair condition), the pavement can be restored to good condition. This can be done by resurfacing or by strengthening the pavement with an overlay — a moderately costly measure that restores structural strength and ride quality to meet traffic requirements for the next several years, thus starting a new pavement cycle. With adequate routine maintenance and timely resurfacing or strengthening, a paved road should never deteriorate into poor condition, which requires far more costly reconstruction.

2.05 A second fundamental relation links vehicle operating costs to road roughness (Table 2.1). Recent research has shown that the effect of roughness on vehicle operating costs is not as large as previously estimated. In so far as comparisons are possible, the new estimates of the increase in operating cost as a function of roughness are on average a quarter below those proposed in an earlier standard work (see Annex, paras 3-4). Overestimates of the savings in vehicle operating costs may have led to mistakes in investment and maintenance decisions, but a far graver error occurs when maintenance policy ignores the share of the vehicle operating costs in total road transport costs. That share is high, except where traffic is extremely light (Figure 2.2). Even a small percentage increase in vehicle operating costs from rougher roads is significant, outweighing the cost savings from deferred maintenance.

Strategies for Road Investment and Maintenance

2.06 Much information about the basic relations governing the process and effects of road deterioration comes from empirical research supported by the World Bank (Box 2.1). The large data set and the relations obtained from it are important contributions to road strategies for developing countries and to policies that encompass both construction and maintenance decisions. A model based on that research has been used in studies of road maintenance in several countries. For Mali, Chile, and Costa Rica, these studies demonstrate the interdependence of investment decisions and maintenance actions and the effect of the quality of information on predictions. (The model and the studies are described in the Annex.) These countries were selected to represent a wide range of transport conditions in the developing world. The results, though specific to the conditions in these countries, illustrate general points about selection of cost-effective maintenance policies and the decision criteria for paving and initial pavement strength. An annual discount rate of 12 percent is used for the analyses reported in this chapter. [4]

2.07 Traffic and road conditions. In establishing standards for road design and maintenance, the key factor is the level of actual and expected traffic. For Chile and Costa Rica, which have relatively higher traffic volumes on their road networks the optimal policy was to keep the most heavily used two-thirds of the networks in good condition while maintaining the other one-third at lower standards. In contrast, for Mali, where traffic volumes are generally very low, the most economical solution was to keep

Table 2.1 Effect of Road Roughness on Vehicle Operating Costs (Economic Costs, Costa Rica, 1984)

Index of Vehicle Operating Costs (GOOD = 100, at IRI of 2.3)

Vehicle class	Road Condition (Roughness, IRI)[a/]	
	FAIR (4.6)	POOR (6.9-9.2)
Small car	106	114-126
Bus	104	109-116
Light diesel truck	111	124-138
Heavy truck	114	129-146
Articulated truck	112	127-144

a/ The dominant effect of road condition on vehicle operating costs is through "roughness," a measure of road surface irregularities standardized by the International Roughness Index (IRI).

Source: From application of the vehicle operating costs submodel of the Highway Design and Maintenance Model. [41] For the Costa Rican context, see [4].

Box 2.1

The Highway Design and Maintenance Standards Study

In 1971 the World Bank initiated what later became a major collaborative program of primary data collection and research -- first in Kenya and later, on a much enlarged scale, in Brazil and India. With participation and funding by several other institutions and governments, over $20 million was spent for data collection and analysis to provide rigorous quantification of key relationships. More than 90 percent of the funds came from the other participants: the governments of Brazil, India, Kenya, and the United Kingdom, as well as the United Nations Development Program. The governments of Sweden and Australia provided technical assistance.

Results of the studies are being issued as a series of World Bank publications, including two volumes on road user costs [6, 41], a volume on road deterioration [27], another on the resulting planning model [42], and two technical papers on measuring road roughness [33, 34]. This research advanced knowledge about basic road deterioration and vehicle operating cost relationships beyond the state of 10 or 15 years ago. It also revealed the complexity of the relationships and their sensitivity to an array of area-specific circumstances. The relationships were formulated on the basis of a larger and more comprehensive data set than was previously available.

To apply this empirical knowledge to the essentially interrelated questions of highway construction and maintenance, the Bank developed the Highway Design and Maintenance Model (HDM) and a companion Expenditure Budgeting Model (EBM). These models are designed to search for the best solution appropriate to a country's circumstances. They do this by exploring multiple combinations of alternative road designs and maintenance options in terms of their effect on total transport costs. The results are then tested for their sensitivity to variations in input parameters and future conditions -- a necessary precaution. The application of the model nevertheless requires a reliable information system and capable staff who can make proper use of the data base and the model.

about one percent of the network in good condition, maintaining the rest at considerably reduced standards as determined by traffic.

2.08 Under these optimal policies, keeping roads in less than good condition does not imply neglecting maintenance. In all cases, drainage and vegetation control are fundamental, as are high standards of patching and basic routine maintenance, even for roads to be maintained at low standards. In Mali, this maintenance is estimated to cost about $6.2 million a year -- about twice the current spending. (This estimate does not include the $9 million required for the backlog of economically warranted rehabilitation and reconstruction of higher-volume paved roads in poor condition.)

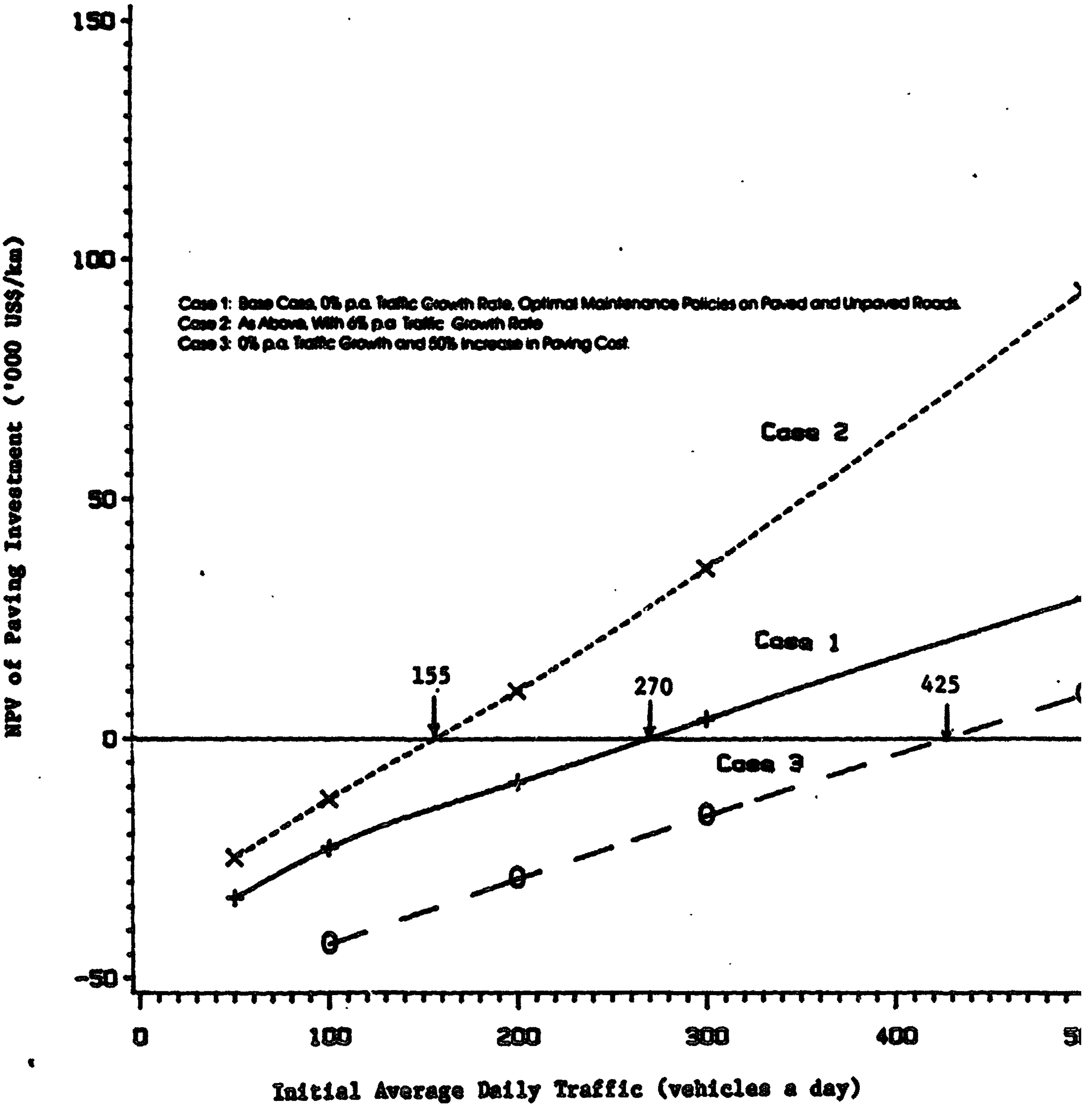
2.09 To pave or not to pave. Decisions about whether or when to pave an unpaved road are subject to many factors, one of which is the expected future growth of traffic. Figure 2.3 shows, for a specific example in Mali, the net present value for paving a gravel road as a function of traffic. The exact traffic level at which it becomes optimal to pave the road is very sensitive to the expected rate of growth of traffic as shown by Case 1 (no growth in traffic) and Case 2 (6-percent annual growth). It is assumed in all cases that proper maintenance will be carried out whether the road is paved or not. The cost of paving is also important: in Case 3 (no growth in traffic but a 50-percent increase in cost), the optimal traffic threshold for paving jumps from 270 vehicles a day to 425. But the penalty for not paving at the optimal traffic level is not very large. Considerations other than traffic may thus govern the choice.

2.10 When the decision to pave is not preempted by present and prospective traffic, it has to be made from a consideration of other factors. Important among these factors is the probability that future maintenance will be done to acceptable standards, on paved and unpaved roads. If the main uncertainty is about the availability and adequacy of future maintenance funds rather than the ability to plan and execute maintenance, the best policy will be to defer paving. The present value of the total life-cycle transport costs associated with a gravel road (even though suboptimally maintained) will be less than that for a paved road if there is uncertainty about the availability of funds at the stage when paved road deterioration begins to accelerate steeply. Conversely, if uncertainty mostly surrounds the country's maintenance capacity, early paving (and therefore, fewer roads) will be indicated. The present value of the total life-cycle transport costs associated with an unmaintained gravel road will exceed that of an unmaintained paved road down to the point at which they become less serviceable. These conclusions, stated in broadest terms, result from the joint effect of discounting and the nonlinear deterioration of paved (but not unpaved) roads.

2.11 Strong or weak pavements. An important question in determining the paving strategy is whether the staged construction of pavements makes economic sense: that is, beginning with a low-strength design and strengthening the pavement later to accommodate heavier traffic and axle loadings. The answer depends on the quality of maintenance that can be expected on the (initially) lower strength road. The question was explored for conditions in

Mali and Costa Rica, assuming 3 to 4 percent annual growth of traffic and two levels of axle loads. With a 75-percent to 90-percent probability of adequate maintenance, staged construction would be economical for initial traffic flows up to 2,000 or 2,500 vehicles a day, depending on axle loads. But with only a 50-percent probability of adequate maintenance, strong pavements should be built initially, despite the higher construction cost, to compensate for unreliable maintenance -- staged construction, in this case, would remain the preferred alternative only at traffic volumes under

Figure 2.3 Breakeven Traffic Volumes for Paving a Gravel Road.



1,000 vehicles a day with light axle loads. In all cases pavement designs should conform to minimum design and constructon specifications.2/

2.12 Some countries made expensive mistakes by staging the construction of pavements under assumptions of adequate maintenance and restricted axle loads, assumptions that proved invalid. Heavy loads accelerate road deterioration, and even with optimal maintenance policies, the average life-cycle roughness remains higher with heavier axle loads. Empirical evidence shows that pavement damage increases exponentially (to the power of 4) with increased axle loads. But the regulation of axle loads has proven exceedingly difficult and expensive. Many road authorities are now building stronger and more expensive pavements than would be necessary with effective axle load control. Even if it were practicable to enforce axle-load regulations, axle load limits should be increased beyond the prevailing 8-10 ton single (and 13-16 ton tandem) axle loads -- because the economic gain from the use of larger trucks outweighs the increased damage to roads. [32]

Tactics under Budgetary Constraints

2.13 Road authority funding often is not enough for carrying out the economically optimal level of maintenance. And when budgets are constrained, the best policy is not simply to reduce all categories of maintenance spending equally, as is often done. The situation calls for revising policies and using different maintenance options. The management of retrenchment (and, in extreme cases, network contraction) has not received much analytical attention. But some rules can be stated to control the retrenchment process and prevent it from becoming haphazard.

2.14 In establishing spending priorities, the tradeoffs between road agency costs and net benefits of different maintenance strategies are not normally examined. As long as the net present value of a maintenance option is positive, it is deemed justifiable -- whatever the cost to the agency. But if the analysis is extended to road agency expenditures, there appears a big margin for reducing them without making similarly large cuts in the benefits to road users. Figure 2.4 shows net present values for alternative maintenance options applied to a specific class of roads. The line connecting the points that are highest in net present value for given agency expenditures is the efficiency frontier. The optimal strategy, given unlimited funds at the assumed discount rate (12 percent), would be that shown at point I. In addition to basic routine maintenance, this strategy would require an immediate application of an 80-mm overlay, followed by 40-mm overlays whenever roughness exceeded 3.5 IRI.

2.15 Note that the efficiency frontier is rather flat immediately to the left of the optimum point -- and that alternatives in this zone can

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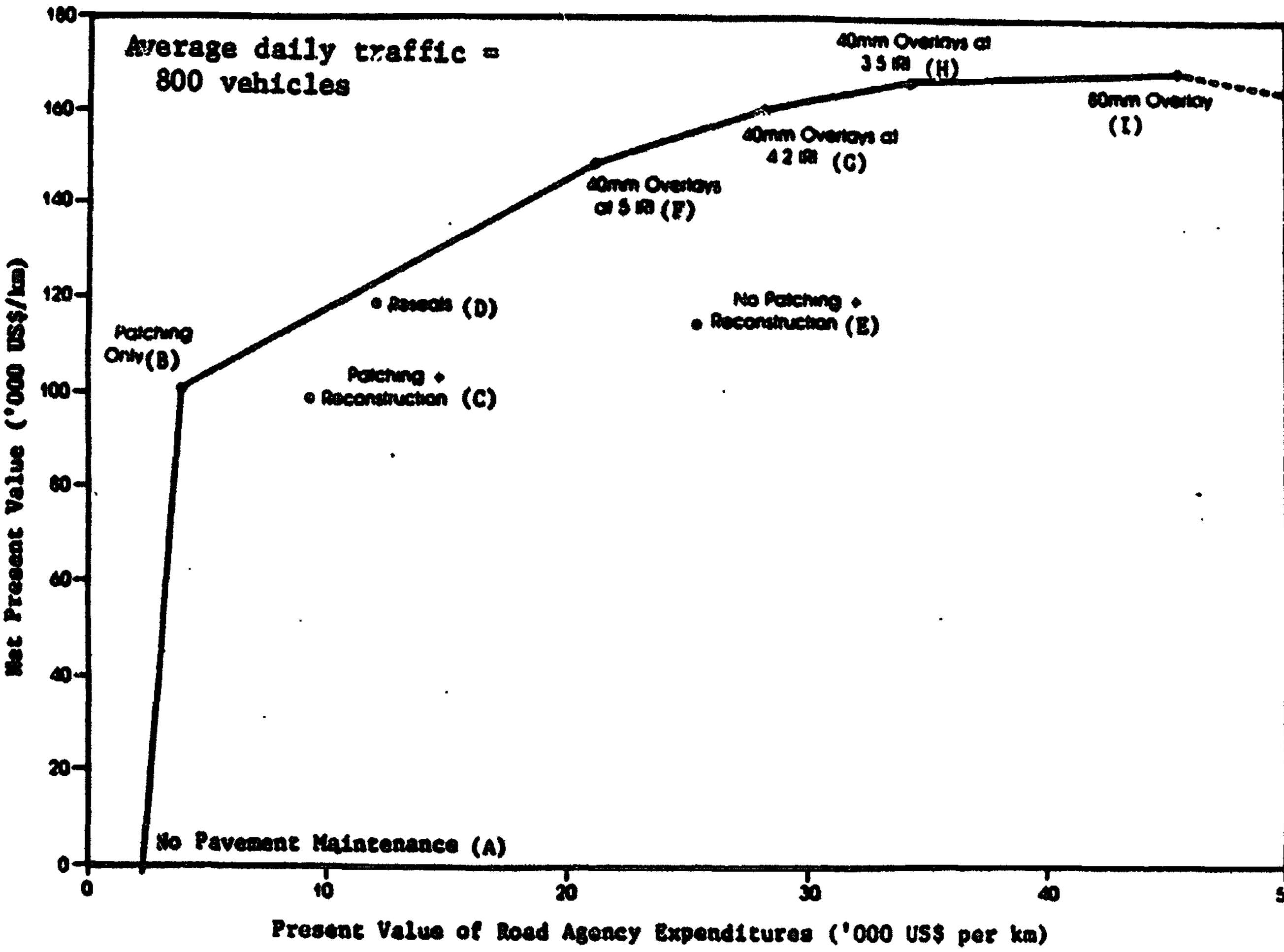
2/ A technical option that has not been sufficiently explored in developing countries, particularly in the humid tropics, is the use of portland cement concrete pavements. Where properly designed and constructed, concrete pavements, though initially expensive, can provide a long initial service period (15-20 years) that is nearly maintenance free.

Figure 2.4 Net Present Value Versus Agency Expenditures for Alternative Maintenance Strategies for a Paved Road in Fair Condition



<u>Note:</u> See the Annex for specifications of the maintenance alternatives represented by each point on the graph. It is possible to operate on the frontier between two of the points by using one policy on some roads and the other policy on others. For example, a combination of policies "F" and "G" could use funds equal to those required for policy "E" and achieve a net present value on the frontier. Thus policy "E" is inferior and should never be used. Similarly, any other points below the efficiency frontier represent policies that should not be used. In the circumstances of the case illustrated above, policy D (reseals) is an inferior solution, compared to a combination of patching only (B) and overlay (F) options. In other cases, resealing will often turn out to be an efficient maintenance measure to prolong the functional life of pavements. The relative position of various policies will change significantly with changes in discount rate and the relative cost of different maintenance alternatives.

significantly reduce agency costs with only a small impact on total transport costs. As agency expenditures are cut back, vehicle operating costs increase, but by only a little more than the savings in maintenance expenditures. Moreover, the tradeoffs in the region near the optimum do not imply higher future costs for road rehabilitation. It is simply a matter of maintaining the roads at a somewhat rougher level, with a consequent saving to the road agency and somewhat higher costs to road users. In general, this sort of tradeoff was found in the vicinity of the optimal strategy for most other cases studied.

2.16 But as the budget departs further from the optimum and maintenance is cut back correspondingly, vehicle operating costs increase by much more than the savings to the road agency. In addition, the changes in maintenance policy entail increasingly greater risks of pavement failure, leading to much higher costs for reconstruction in the future. In sum, the range of good maintenance policies is wide, but below a critical level the consequences of further reduction become destructive.

2.17 Sometimes a government must take austerity measures to deal with a national emergency or adjust to difficult economic conditions. Normal budgets may have to be cut back for a year or several years, with the intention of restoring them later. In such circumstances, road maintenance is often deferred. If roads are in good condition, the deferral may not be too costly. Increased roughness due to undermaintenance will increase vehicle operating costs somewhat, but roads that decline to fair condition can be restored with a modest additional expenditure. If, however, the deferral continues too long or if roads are in only fair condition at the start, the impact on vehicle operating costs will be greater. And paved roads declining to poor condition will require far more expensive reconstruction later on. That is why road agencies should consider future budget interruptions when making choices about their design and maintenance policy. And one way to limit the adverse impact of future interruptions in funding is through good maintenance in normal times.

CHAPTER 3: THE INSTITUTIONAL CHALLENGE

3.01 Choosing the best maintenance policy will remain an academic exercise until institutions can efficiently put the policy into practice. Experience has been disappointing. The World Bank advanced more than $1.2 billion between 1971 and 1985 for training, technical assistance, and management consultancies to improve the organization and management of road administration in developing countries. Other lenders and donors and the developing countries have also devoted substantial resources for this purpose. Despite these efforts, it has been difficult to establish self-sustaining institutions that can manage road maintenance efficiently or use external resources effectively.

3.02 Experience has provided no standard solutions to the problems of institutional performance. Without proven formulas, institutional development has had to proceed by continuous, local experimentation. Experience has, however, identified constraints on improved performance and some general principles worth pursuing.

The Constraints

3.03 Three factors have worked against the institutional development for road maintenance:

- The nature and constitution of the typical road agency, marked by conflicting objectives and functions and a lack of incentives.

- The weak public pressure for better roads.

- The inadequacy and unreliability of funding. [16]

3.04 Structure and functions of the road agency. World Bank efforts to improve the management of roads and road maintenance have focused on road authorities, which typically operate as public sector monopolies. These agencies are generally responsible for three functions: 1) planning the development and maintenance of roads, 2) negotiating and overseeing road work by contractors, and 3) constructing and maintaining roads using its own work force (force account). The division of work between contractors and force account varies by country. Contractors usually undertake new construction and large rehabilitation projects, while road agencies do routine maintenance with their own work forces. Resurfacing operations are sometimes shared, sometimes not. In some countries contractors also do routine maintenance, and in some the agency's work force also constructs new roads.

3.05 Contracted works for new construction and rehabilitation normally constitute the greatest part of agency expenditures. But direct execution of maintenance works, accounts for the major share of road authority employment and for a disproportionate share of difficulties.

3.06 Conflicts may arise when a state organization combines the planning and control of construction and maintenance operations with the direct execution of works. Internal control is blunted and efficiency prejudiced when direct execution receives too much emphasis, if only because of the political significance of the large labor force employed. Already weak incentives for efficiency are undermined by the constraints inherent in the public service. Civil service rules circumscribe managerial decisions. Deficient salary scales and promotion systems make it difficult to retain competent staff. And employment objectives frequently smother the technical work of the authority, distorting its decisions (Box 3.1).

3.07 Weak public pressure. Because road agencies do not operate road transport services, they do not suffer directly from bad maintenance. Nor do they normally sell services to road users in a competitive market. They thus do not bear the full cost of neglected maintenance. Nor are they subject to market pressure, as railways are. Also absent is the pressure from direct dealings with the public -- pressure felt by public health, education, and transport services, for example. Truckers rarely experience enough competition from other transport modes to make them complain about the high cost of operating vehicles on bad roads, and car owners and businesses are too dispersed to form effective pressure groups for better roads. Furthermore, the effects of the road authority's neglect are unlikely to be perceived before the problem has become acute. Without pressure groups to prod them, politicians and administrators have little concern for the roads, and the road agency becomes a facility for political patronage and unemployment relief.

3.08 Inadequate budgetary provision. Without political support or market pressure, the budgets for road maintenance are often unrelated to known requirements. Because much of the budget tends to be committed to the wages of an unnecessarily large labor force, the disposable portion fluctuates much more than the total when budgets are cut or prices rise. A small cut can bring much of the agency's work to a standstill because of its inability to buy fuel or spare parts. Moreover, even when funds have been appropriated for maintenance, political or private interests put pressure on road authorities (or their financial sources) to divert funds to other purposes. Such interference, often one of the biggest managerial challenges, can be controlled only in the political arena.

The Search for Solutions

3.09 Accountability. A striking absence of accountability is a common cause of the institutional failure of road agencies. Planning, supervision, and execution are normally combined in the same organization. Road agencies seldom link the allocation of funds to explicit physical plans and rarely perform post-project evaluations. To improve accountability, planning and supervision must be separated from execution of works, and procedures must be introduced to ensure the evaluation of project results. One way of doing this is for the road agency to award maintenance contracts through competitive bids, and then to supervise and evaluate the work closely. Raising the visibility of maintenance objectives and performance is equally important.

Box 3.1

Overstaffing and Resource Imbalances in Kenya

The effects of the general budgetary squeeze on operating funds (for fuel, spare parts, and bitumens, for example) has been exacerbated in Kenya by two parallel developments affecting the Roads Department. One is the decision to integrate casual labor with the permanent work force. The other is the implementation of the District Focus Program, a broad-based effort to decentralize government functions. Until 1982 the (central) Roads Department employed an average of 1,000 permanent staff and about 9,500 casual workers. Wages and emoluments amounted to 6.7 million Kenyan pounds (KL), and operating funds totaled KL 9.7 million, which was already inadequate.

Three years later, however, the situation had deteriorated dramatically because of increases in the permanent work force and decentralization of road agency functions. The Roads Department's casual workers (and some personnel from other minor departments) had been integrated with the permanent work force at the district level, and the number of personnel had risen from 1,000 to 14,600. Of the KL 10.5 million allocated from the central budget to the districts, more than 90 percent went for personnel-related expenditures, leaving little for operating expenses. Meanwhile, funds for operations that were centrally controlled (including most equipment-based operations) were down to KL 6.3 million.

Unless this is achieved, the chronic underfunding of maintenance in developing countries will be difficult to reverse.

3.10 Also essential for an agency's accountability is monitoring by an independent authority. Performance audits should relate financial flows and physical performance indicators to the state of the roads. An information system for collecting such data — needed for planning and for monitoring performance — is therefore an essential ingredient of good policy. The data can also be used to make an independent and public assessment of the agency's performance. In the United Kingdom, for example, county road authorities have to publish annual reports showing their costs, comparing them with private contractors' charges. [9]

3.11 Public awareness. Wider public awareness, including that of potential interest groups (contractors, exporters, transport enterprises) is important for shaping policy and mobilizing support for programs to restore and maintain roads. The Swedish National Road Administration, for example, carries out periodic surveys (using questionnaires) to gauge how the public perceives its work. It then uses the results of these surveys to redirect its policies and operations. It also uses the results to influence the Parliament and the Government to ensure adequate highway funding. The public information programs of professional societies and trade associations — such as the American Society of Civil Engineers, the American Automobile Association, and the National Asphalt Association — have also helped to arouse public concern about the state of roads in the United States. [7] In France the national and regional associations of contractors (Fédération Nationale des Travaux Publics and Fédération Régionales des Travaux Publics) perform a similar role, lobbying for increased public spending on roads. And in Japan, the Road Association, an interprofessional body with private and public representation, promotes public interest, both technical and general, about the needs and condition of the country's roads and acts as an effective lobby at all levels of government.

Elements of Reform

3.12 Management systems that work in developed countries have not always improved the operation of road maintenance institutions in developing countries. And when they do, it is not clear why. Reforms will thus have to be experimental, starting with an understanding of the institutional environment and focusing on accountability.

3.13 Decentralization or functional separation. Decentralizing the organizations for road maintenance has often been advocated as one of the first steps in reform. The presumption is that it would improve responsiveness to local needs and reduce the management difficulties inherent in wide geographical coverage. One contrary argument is that technical and managerial staff would be spread thin. Another is that the increased political sensitivity could divert maintenance funds to more popular (or more conspicuous) but less worthwhile construction activities. It could also lead to the employment of redundant local staff — as in Kenya and Honduras. The Bank's review of experience is not conclusive on this point, showing little correlation between success in road maintenance and the degree of centralization. That leaves pragmatic case-by-case experimentation as the only prescription.

3.14 More obvious is the need for separating the execution of works from the planning and control functions, for that would help to insulate planning and control from the pressures inherent in operating a works program. If execution were turned over to private contractors (operating under competitive incentives) there would be benefits from the greater freedom to procure and manage resources. Private contractors offer better prospects for developing an efficient, lasting institutional capacity for carrying out road maintenance services. They can also constitute an informed group directly interested in the adequacy of road maintenance budgets. Experience suggests that private competitive organizations use and maintain machinery more effectively than do government agencies (Box 3.2).

3.15 A review of experience with the contracting of maintenance in nine countries found that roads under contract are generally well maintained in seven of them (Argentina, Brazil, Central African Republic, Ghana, Kenya, the United Kingdom, and Yugoslavia). [15] In the other two (Colombia and Nigeria), the problems encountered in initial experiments are being evaluated to find solutions. Evidence suggests that private contractors can perform work at lower cost than government organizations. In one case with fully comparable costs under similar conditions (Ponta Grossa, Brazil) maintenance by the permanent work force cost 60 percent more than contract maintenance. Contractors have been attracted to maintenance opportunities, even in remote areas. Very often, small local contractors can operate in remote areas more cheaply than can the central road administration or larger contractors.

3.16 The desirability of contracting a major part of ongoing routine maintenance and resurfacing deserves wide consideration. Retaining a small government maintenance capacity can ease the transition, provide back-up for emergencies, and reduce the risk of replacing a public monopoly with a cartel of private interests (as occurred in Nigeria and to a lesser extent in Brazil). Japan's policy of relying on contracting for road maintenance is reinforced by numerical limits on the labor force that government agencies may hire. An increase in the demand for civil works results automatically in resort to contractors. Even the field offices of the local public works administrations can let maintenance contracts of a limited, but far from neglibile value. Equipment in public ownership is kept at minimal levels, just enough to meet emergencies. Thus the investment in government-owned workshops and space parts inventories is negligible. The United Kingdom has had promising initial results with a program (begun in 1981) that requires the agency's work force to compete with private contractors. [9] This competition stimulates pressure for efficiency on both sides and has provided an incentive to assemble reliable cost data.

3.17 <u>Contracting techniques and skills</u>. The use of contractors can reduce the burden on the road authority, but it increases the need for supervisory management. Harnessing the profit motive to get the required work done well, on time, and at reasonable cost requires knowledge of contract

Box 3.2

Low Equipment Utilization in West Africa and Latin America

Road maintenance surveys by the World Bank in 1985 for West Africa and Latin America found vehicle and equipment utilization rates far below what generally is regarded as efficient (1,250 hours a year). In West Africa, the average annual hours of operation ranged from 420 for rollers to 840 for dump trucks. In Latin America, utilization averaged 750 hours for equipment and 800 for vehicles; crushing plants were utilized even less, and asphalt finishers had the lowest rate -- 420 hours a year.

In West Africa, lack of spare parts and fuel appear to have been major causes of low utilization. About 40 percent of the road authorities received only half the funds needed to purchase spare parts to keep their fleets fully operational. Fuel expenditures in nine countries in 1982 were only about one-third the amount needed for 1,000 hours of operation. The lack of spare parts hindered maintenance, and the shortage of fuel restricted operation.

Low utilization is harder to explain in Latin America. With three exceptions, road authorities in the countries surveyed had enough funds for spare parts to operate the fleets 1,000 hours a year. About 40 percent of the agencies had less than two-thirds of the funds needed for fuel for 1,000 hours of operation a year. But the rest did sufficiently better to raise the regional average to 82 percent of the funds needed for fuel. Poor equipment management and, possibly, too few well qualified operators and mechanics may partly explain the low rates of utilization.

design. The contract should not provide uneconomic incentives (as in a cost-plus contract) or restrict the contractor's freedom to seek cost-saving methods and sources of supply. Where institutional capability is limited, consultants, specialists, or management-services contractors can help to develop management systems and contract instruments -- and provide training for government staff and contractors.

3.18 If well-established domestic contractors are not available, the trial introduction of small contracts (say, for routine maintenance that is technically simple and requires little investment) can reduce risks and help develop the capabilities of government and contractor personnel. All successful contracting schemes have involved close coordination between the government and contractors in defining and planning the work. Such schemes have also changed the role, sources, and contractual modes of foreign technical assistance.

3.19 Human resources. Better use can be made of human resources in several facets of road maintenance. Unskilled labor can be substituted for machinery -- a cost-effective solution when wages are low, activities are properly organized and managed, and suitable incentives are built into the system. [8] And many countries have had good results with the simple "lengthman" system. Under this system, people living alongside the road are responsible for maintaining it, with payment and continuing employment contingent on satisfactory performance.

3.20 Low and inflexible civil service salary scales make it difficult for government agencies to retain competent managers, engineers, technicians, foremen, mechanics, and others with special skills. Sometimes incentives can help retain the most productive staff. The roads authority in Ethiopia, after some trial and error, devised a bonus scheme based on work-unit productivity. Agencies in several other countries use special allowances to encourage field supervision by middle-level managers. But despite these and similar schemes, staff turnover is likely to continue to be high. Road authorities may as well recognize that one of their useful functions is to serve as a training and proving ground for personnel who will move on to the private sector.

3.21 The personnel management -- or mismanagement -- is the area with the most potential for improvement. Staff must be motivated -- and inculcated with a sense of duty and accountability -- with good performance recognized and rewarded. Recruitment and appointment to senior positions must be based on competence, not patronage or antiquated seniority-bound civil service regulations and policies. Weak performance is all too often blamed on inadequate training when it stems from inadequate, nonexistent, or unenforced personnel management policies. Training whose importance cannot be emphasized enough must be an integral part of personnel management. For such dispersed work activities as road maintenance, road extension services can be modelled on the training and visit system used in agriculture to provide an effective and fairly low-cost means of training maintenance staff. [45, 46]

Technical Assistance

3.22 Technical assistance for road maintenance has traditionally focused on advisory services, management systems, and training for road authority personnel. It is less common for technical assistance personnel to act in an operating, rather than advisory, capacity.1/ As a result, providers of technical services have little exposure to risk, few incentives for improving performance, and only indirect responsibility (if any) for measurable output.

3.23 Some schemes have tried to establish performance incentives for suppliers of technical assistance by redefining their role and leaving them more of the risk. But traditional suppliers of technical assistance generally lack the financial wherewithal to accept significant risks. So it may be desirable to look to new sources of assistance, such as international civil engineering contractors. These companies are accustomed to risk-taking ventures and performance-related incentives, and their staff have the requisite qualifications and are accustomed to working together as management teams in developing countries. Another option is a "twinning" arrangement between a developing country road agency and a partner institution in a more advanced country. Such arrangements can facilitate regular exchanges of middle-level managers and technical staff. They can also provide for the transfer of technology, procedures, and systems. [47] The Federal Highway Administration of the United States has collaborated in such arrangements with the highway authorities of Argentina, Ethiopia, Jordan, Liberia, Nepal, Philippines, and Turkey, among others (Box 3.3). [48] France, through its technical services agencies, has also provided assistance to develop similar institutions in Algeria, Cameroon, and Cote d'Ivoire.

1/ Among the exceptions are the technical assistance programs of France and the United Kingdom, which have provided technical staff to assume senior line positions in the highway agencies of such countries as Djibouti, Cote d'Ivoire, Gambia, Malawi, and Niger. The effectiveness of such technical assistance will be greatly enhanced if the technical ministries of the sponsoring countries provide adequate backstopping.

Box 3.3

Twinning of US and Turkish Highway Organizations

In 1947 the United States initiated a cooperative program to help Turkey develop a highway organization capable of constructing and maintaining an expanding road system. The US Public Roads Administration (PRA) was entrusted with this task. The first phase of the assistance to the Turkish highway administration consisted of the PRA staff's assessment of highway development in Turkey and a formal agreement with the Turkish government covering the objectives and arrangements for implementing the program.

PRA's staff initially provided the core organization for the work. Specialists were added to the organizational units as required, but as soon as Turkish personnel could take over an organizational unit, that unit was dropped from the technical assistance program. The first division to be transferred to exclusive Turkish administration was the Planning and Programming Division.

When the technical cooperation program began in Turkey, local counterparts could not be found for many of the technical divisions, such as Materials or Survey and Design. To fill this gap, training programs were organized with the better graduates becoming instructors for new classes. While learning on-the-job, the Turkish personnel gained further practical experience as they built and maintained the highway system. And when recruiting satisfactory equipment operators proved difficult, the Turkish Army supplied men and officers for the program.

The last US advisor left Turkey in 1958. By then, the Turkish General Directorate of Highways had evolved into a first-class highway organization capable of maintaining 27,000 miles of all-weather national and provincial highways, most of which were improved or constructed during the period of the US technical cooperation.

Source: America's Highways 1776-1976, US Department of Transportation, Federal Highway Administration, Washington, D.C. (1976). [48]

CHAPTER 4: FINANCIAL REQUIREMENTS

4.01 Few developing countries have spent wisely or enough on road maintenance. Not all roads have to be maintained in the best condition to maximize economic returns, but heavily used roads should not be allowed to deteriorate -- especially when a fairly small, properly timed expenditure for maintenance would make reconstruction unnecessary. The costs for restoring deteriorated and rapidly deteriorating roads are substantially more than most developing countries have been spending. But far greater sums are at stake if the situation is not handled better over the next decade.

The Aggregate Picture

4.02 The financial requirements of the road deterioration problem have two parts. One is the cost of economically warranted restoration (rehabilitation and reconstruction) of the roads that have been allowed to deteriorate to poor condition. The other is the future annual cost of economically warranted maintenance of the whole network.

4.03 The cost of restoration. The cost of economically warranted restoration of degraded main roads for 85 developing countries is about $43 billion (Table 4.1).1/ Even without a claim to accuracy, the number provides an order of magnitude. Bridges and large tertiary and lower-order networks were not included, but a speculative estimate for such components is about $15-25 billion. Under limited budgets, only some of these components would qualify as economically warranted restoration. The estimates also exclude about $3 billion for some rehabilitation of very low-volume main roads in the poorest countries of Sub-Saharan Africa. Full restoration of these roads would not be economically warranted, although maintenance should be at higher standards than at present.

1/ The estimation procedures are described by Smith and Harral. [35] A few countries in each region account for a large proportion of the region's restoration needs:

Eastern Africa:	Madagascar and Zambia together, 40%
Western Africa:	Nigeria and Ghana together, 58%
East Asia:	China, 56%
South Asia:	India, 64%
Europe, Middle East, and North Africa:	Turkey, Yugoslavia, and Algeria together, 56%
Latin America and Caribbean:	Brazil and Argentina together, 63%.

Table 4.1: Total Expenditures Required to Meet the Estimated Restoration Backlog in 1984
(US$ billion; 1986 prices)

Region	Rehabilitation and reconstruction Paved	Rehabilitation and reconstruction Unpaved	Total	Total as a percentage of GNP Median	Total as a percentage of GNP Range
Eastern and Southern Africa	1.4	0.8	2.2	3.3%	0 - 15.5%
Western Africa	1.9	0.9	2.8	3.2%	1.2 - 36.9%
East Asia and Pacific	7.5	1.8	9.3	1.6%	0.2 - 2.5%
South Asia	7.7	0.9	8.6	3.5%	2.5 - 12.7%
Europe, Middle East, and North Africa	8.4	0.9	9.3	2.6%	0.4 - 7.4%
Latin American and Caribbean	7.9	3.1	11.0	2.0%	0.4 - 22.8%
Total	34.8	8.4	43.2		
(percentage of total)	(81)	(19)	(100)		

Table 4.2: Annual Maintenance Expenditures Required to Prevent Deterioration, 1986-90
(US$ billion in 1986 prices)

Region	Routine maintenance	Resurfacing Paved	Resurfacing Unpaved	Total	Total as a percentage of GNP Median	Total as a percentage of GNP Range
Eastern and Southern Africa	0.2	0.1	0.1	0.4	0.7%	0.2 - 1.8%
Western Africa	0.1	0.1	0.1	0.3	1.0%	0.1 - 3.5%
East Asia and Pacific	0.3	0.8	0.2	1.3	0.2%	0.1 - 0.4%
South Asia	0.1	0.3	0.1	0.5	0.3%	0.2 - 1.1%
Europe, Middle East, and North Africa	0.2	0.5	0.1	0.8	0.3%	0.1 - 0.6%
Latin America and Caribbean	0.5	0.6	0.3	1.4	0.4%	0.1 - 2.8%
Total	1.4	2.4	0.9	4.7		
(percentage of total)	(30)	(51)	(19)	(100)		

4.04 Future costs. Strongly affecting future costs will be the money spent (and effectively used) in the next few years to prevent the deterioration of more roads into poor condition. A remarkably high proportion of the paved network (more than 40 percent in 1984) already is or will soon be in only fair condition, requiring major maintenance to prevent structural failure. Met promptly, resurfacing and routine maintenance needs should amount to about $4.7 billion a year (Table 4.2) over the next few years and then taper off somewhat after the bulge of roads in fair condition passes through. If these needs are not met in time, however, the costs will multiply rapidly. An example of inadequate spending is the $43 billion worth of restoration needed now because of not doing some $12 billion of preventive maintenance over a decade or so.

4.05 Required allocations. The funds needed to prevent further deterioration and to clear the $43 billion rehabilitation backlog (in either five or 10 years) are summarized in Table 4.3. If all countries met the five-year target, the cost would be about $13 billion a year ($4.8 billion for maintenance and $8.6 billion for restoration). For the 10-year target, the cost would be about $9 billion a year ($4.8 billion for maintenance and $4.3 billion for restoration). The foreign exchange requirements would be $4 billion for the five-year target and $6 billion for the 10-year target.

4.06 These estimates are less than economically optimal because they emphasize holding down road agency costs at the expense of higher user costs (especially in the 10-year program). That emphasis implies giving priority to saving roads in fair condition to minimize future restoration costs, even if the social return would be higher from reconstructing heavily traveled roads in poor condition and thereby saving user costs.

4.07 Costs could be reduced by improving the productivity of maintenance, but it is not clear whether such gains are attainable in the short run. There is scope for improving the productivity of some elements of maintenance operations — labor, equipment, and procurement and supply. But such gains are likely to be disrupted if the institutional structure is defective. Even if supported by an infusion of technical assistance, such gains are difficult to sustain without the commitment and dedication of local staff and managers of road authorities. Productivity gains are likely, therefore, to account for only a small reduction in the short-term bill.

4.08 Total road expenditures, including construction, in the 85 countries are estimated at $10-13 billion for 1984, of which restoration and maintenance may have accounted for about 50 percent. With $4.8 billion a year required for future maintenance, little would remain for catching up on the rehabilitation backlog. In many countries the restoration and maintenance budget is too small even to stabilize the road networks in their present condition, let alone rehabilitate them.

Table 4.3

Annual Financing Requirements for Restoration and Maintenance of Roads
(US$ billion in 1986 prices)

	Total cost		Foreign exchange	
	10-year target	5-year target	10-year target	5-year target
Eastern and Southern Africa	0.6	0.8	0.3	0.4
Western Africa	0.6	0.9	0.3	0.5
East Asia and Pacific	2.2	3.1	0.9	1.3
South Asia	1.4	2.3	0.6	0.9
Europe, Middle East, and North Africa	1.8	2.7	0.8	1.3
Latin America and Caribbean	2.5	3.6	1.2	1.7
Total	9.1	13.4	4.1	6.1

Country Differences

4.09 There are wide differences among countries in the financial requirements for road maintenance and restoration, the ability to marshall and allocate the needed resources, and the capacity to use additional resources effectively.

4.10 Financial constraints. The financial severity of a country's road restoration requirements can be gauged in two ways. One is to estimate the improvement in current funding for maintenance that would result from reallocations of the overall sector budget. The other is to look at the rate of growth of real GNP per capita during 1975-85. The first criterion shows what could be done with current road funds. The second gives a crude indication of the potential for increasing those funds. Although any indicator of the potential for increasing funds is open to question, the growth of real GNP per capita is believed to be a valid indicator for most countries.2/

2/ There are bound to be exceptions: the oil-producing countries and others linked to them economically had unusually high growth rates during 1975-85 but were set back by the recent drop in oil prices and are now facing adjustment problems.

4.11 Current road budgets (from domestic sources and, in some cases, external assistance) were placed in three broad classes according to their adequacy for road network restoration:

- Sufficient financing capacity. Current road funding, if reallocated, would be sufficient for adequate maintenance of the network, for complete restoration within five years and for new construction amounting to at least 20 percent of the total.

- Moderate to marginal financing capacity. Current funding would have to be increased by up to 50 percent and new construction held to 20 percent of the new total to carry on adequate maintenance and complete the restoration in 10 years.3/

- Insufficient financing capacity. Even if current funding were increased by 50 percent and new construction were held to 20 percent of the new total, funds would be insufficient to complete the restoration in 10 years.

4.12 These criteria were applied to 61 countries for which some expenditure data are available (Table 4.4). More than half the countries with insufficient budgets to finance their road requirements (11 of 16) had negative rates of real GDP growth. Of these, nine are in Sub-Saharan Africa, where extensive road building and paving in recent decades set the stage for today's rapidly worsening maintenance situation. These countries have the greatest need for increasing their road budgets and the poorest prospects for doing so. Along with their neighbors in the table, they constitute the hard core of the road maintenance problem in the developing world.

4.13 A somewhat different problem affects China and several countries in South Asia: India, Pakistan, Burma, and Bangladesh. In general, many of their roads were built long ago to standards of strength and geometry that are totally inappropriate for today's traffic. Although these roads, too, have deteriorated extensively, many of them should not be rehabilitated. Instead, they should be replaced by roads of a capacity adequate for present and expected requirements.

4.14 Reallocation of funds. Leaving aside the special needs of countries with obsolete networks, the reallocation of funds from new construction to rehabilitation and maintenance will be necessary for almost all the other countries in Table 4.4 unless they can increase the road budget significantly. For many, the reallocations will have to be drastic. Even countries with "sufficient" financing capacity will have to shift funds from one category to another — which in many countries is difficult because of the budgeting process. Some have separate national budgets for capital and current expenditures, with construction in one and rehabilitation and

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3/ There is a wide definitional gap between the first two categories. None of the countries fell within that gap, indicating a clear distinction between the two groups.

Table 4.4

Road Restoration and Maintenance: Financing Capacity in 61 Developing Countries

Annual growth of real GNP per capita (1975-85)	Capacity to finance required restoration and maintenance based on recent highway budgets a/		
	Sufficient	Marginal	Insufficient
Over 2.5%	*Korea *Yemen AR *Cameroon *Lesotho *Indonesia	*Botswana Egypt *Paraguay *Thailand Tunisia Algeria Yugoslavia	*Yemen, PDR Burma Pakistan Sri Lanka
0% - 2.5%	Hungary *Colombia Turkey *Rwanda *Burundi *Oman *Nepal Honduras Ecuador *Malawi Philippines Dominican Republic	India Morocco Brazil Chile Portugal *Burkina *Benin *Kenya Mali Guinea	Bangladesh
Less than 0%	*Papua New Guinea *Niger *Cote d'Ivoire *Nigeria	*Swaziland *Costa Rica Uruguay Zimbabwe *Central African Republic *Togo Argentina	Sierra Leone *Mauritania Zambia Tanzania *Senegal Madagascar *Gambia *Liberia Zaire Jamaica Bolivia

Note: Countries are listed in descending order of annual rate of growth of real GNP per capita during 1975-85.

a/ The recent national highway budgets (1981-85) used for this analysis include, in certain cases, external borrowings or grants. The assessment of financial capacity is somewhat subjective as highway budgets fluctuate significantly over time in many countries. See text (para. 4.12) and [35].

* Countries with recently expanded or improved networks.

maintenance in the other. And in many countries, road construction is part of the general development plan — controlled by a special office or ministry, not the ministry or bureau responsible for maintenance. In such a system, reallocating road funds from construction to rehabilitation and maintenance is almost impossible once the budget is drawn up. (A change in allocations would require a top-level decision before budgets are submitted. Such a decision would probably encounter strong resistance from the entity whose construction funds were to be reduced.)

4.15 Reclassifying the budget could ease the consequences of separating construction from rehabilitation and maintenance. For example, resurfacing and rehabilitation of worn-out roads could reasonably be classed as capital rather than recurrent expenditures. Capital project planners might then pay more attention to the need for maintaining older roads and for assessing the future maintenance requirements of new construction projects. The budgetary constraints on rehabilitation would also be less rigid. Such a reclassification should also be useful in reorienting the programs of external aid agencies. Another possibility would be to integrate capital and current budgets and to select maintenance, rehabilitation, and new construction projects on the basis of their economic worth — taking into account future streams of maintenance requirements and road user savings in each case.

4.16 Absorptive capacity. Money is not enough, because expanding the capacity to use funds effectively can be very difficult. Most of the countries considered here will have to expand their rehabilitation and maintenance operations, whether by shifting resources from construction or by other means. Road maintenance agencies will have to handle maintenance efficiently and on a much larger scale than before. All this is likely to require a tremendous expansion of the maintenance capabilities of the government, or private contracting firms, or both. Machinery will have to be acquired. Operators and mechanics will have to be trained. And above all the managers and staff of the road agency will have to learn how to plan, manage, and supervise maintenance work efficiently on a larger scale.

4.17 Expansion may be especially troublesome for countries with recently expanded networks of paved roads. Many of these countries have little experience with maintenance. Nor are they prepared for timely and adequate maintenance that will prevent the need later for far more expensive rehabilitation. Slightly more than one-half of those 30 countries included in Table 4.4 that have largely new paved network are judged to be problematic in terms of their absorptive capacity. Such judgements, based on Bank experience, may be subjective but the overall balance is realistic. The worst combination of problems afflicts some Sub-Saharan countries with relatively new networks: insufficient financial capacity, negative growth rates, and problematic institutional capacity.

Marshalling Domestic Resources

4.18 Funds reallocated from new construction and gains in efficiency will seldom be sufficient to finance the swelling costs of restoration and maintenance. A common method for increasing revenues to finance larger road expenditures is to raise road user taxes and other charges. But in many countries, revenues from road users already exceed (non-urban) road expenditures by a wide margin; so wide that urban road expenditures could not possibly account for it.4/ Taxes on vehicles and supplies are a common and convenient source of general revenue -- often an essential source where the capacity to tax is limited. But high road user taxes may distort transport costs and lead to economically inefficient business decisions about location, production, and investment. When distortions exist, taxes should be raised only after their structure is adjusted to reduce distortions. For example, where heavy vehicles pay less than the cost of the damage they inflict on roads, a tax increase should be structured not only to raise more revenue but also to encourage the use of multiple axles to reduce road damage. To the extent that additional levies on road users are translated into better roads, they will reduce (not increase) road user costs.

4.19 Earmarking revenues. Practically all the arguments of fiscal economics go against earmarking taxes for such specific purposes as road maintenance. Earmarking has nevertheless surfaced in a variety of developing and developed countries and it should not be ruled out from consideration in two cases. In one, where fiscal control is weak and revenue allocation and disbursement are subject to seepage or long delay -- earmarking can assure that the government's decision to maintain and rehabilitate roads is translated into practice. Short-circuiting the budget may then make for a more rational use of resources. In the other case -- where a special tax is to be levied (or a rate raised) to finance road rehabilitation -- the principles of benefit taxation apply. The taxpayers, within a well-defined clientele, know what they should expect to get in return. Such a targeted tax, like the earmarking scheme, will have a limited duration.

4.20 In either case, earmarking can be recommended only if the fiscal integrity of the receiving authority (say, a road fund) and its determination to apply the funds according to economic priorities are assured. A frequent problem is that money earmarked for the road fund does not find its way there or is used inefficiently or for purposes other than road maintenance. One of the few reasonably successful schemes in developing countries emerged only after much trial and error in the Central African Republic (Box 4.1).

4/ Because expenditure estimates cover only nonurban roads, it would be desirable to separate revenues derived from urban road users and those from nonurban users. But this is not possible because few taxes and fees are tied to the locations where the vehicles are used. (See Statistical Table C).

Box 4.1

The Experience with Earmarked Road Funds in the Central African Republic

In the 1960s and 1970s the Central African Republic failed twice in earmarking funds for roads. The first road fund was subject to so much discretion that the earmarking had no practical effect and the fund was abandoned after three years. A second fund, set up in 1970 in connection with the World Bank's First Road Project, was designed to avoid the earlier shortcomings. But the amounts earmarked were inadequate, payments were erratic, and more money had to be sought through budgetary appropriations.

A third road fund, instituted in 1981 in connection with the Fourth Highway Project, is still functioning. As a public establishment with financial autonomy, the fund has the sole function of financing road maintenance. Revenues come from an increased fuel tax, which the government adjusts yearly to maintain the fund's capacity to do its work. The fund is under a ministerial management committee, on which road users are represented through the Chamber of Commerce.

This third road fund has also had some problems, none fatal. At one time, it had difficulty collecting the revenues. At another time, the government forced the fund to pay for a project outside its mandate. Despite these and other problems, the fund has improved road maintenance by raising the level and increasing the regularity of funding.

External Financing and Assistance

4.21 The sheer size of the task now facing many developing countries implies massive demands for external financing. The foreign exchange components of the financing requirements range from 30 percent for routine maintenance in middle-income countries to 70 percent for restoration of paved roads in low-income countries. In many cases, external financing will have to cover more than the foreign exchange component to preserve the infrastructure. And in the group of countries at the hard core of the problem, no solution is conceivable without external financing.

4.22 External financing will have to be focused on restoration and maintenance if the countries' efforts are not to be diverted to lower priority investments. In World Bank lending for highways, this focus has progressively sharpened. Over the decade ending 1985, 53 percent of World Bank lending for highways ($5 billion of $9.4 billion) was for rehabilitation, maintenance, and technical assistance largely related to maintenance. Some multilateral and bilateral agencies, particularly those with a longer experience of providing assistance for highway development, also raised the share of maintenance and rehabilitation in their financing of roads. But most of them, continued during 1981-84, to provide assistance for new construction, even to countries with mounting maintenance backlogs. Bilateral aid tended to have a higher proportion of new construction and improvement works than did multilateral assistance (Table 4.5).

4.23 In general, it makes sense to use external finance primarily for increasing a country's capital assets — and domestic finance for covering current costs, such as those for maintenance. (This is the tendency in most countries in East Asia and in Europe, the Middle East, and North Africa.) It also makes sense to regard the willingness and ability of a country to pay for maintenance — an ongoing cost of road use — as a test of good internal management. There naturally are exceptions, most obviously when countries have suffered major calamities, when the structure of demand has changed considerably, or when the policies of lenders are distorting factors. None of these exceptions will, however, justify lending for new construction if the roads are in serious disrepair. If donors and lenders restrict financing to the foreign exchange cost of projects, and especially if they show a strong preference for new construction, they tempt recipient countries to divert their limited funds to such projects — as leverage to increase the supply of foreign aid. Under these conditions, it is not surprising that maintenance is neglected, especially in the poorest countries where foreign funding plays a big part in determining resource allocation. Maintenance work is then starved of the imported fuel, bitumen, and spare parts needed for the efficient use of equipment and labor. In short, the incentives are biased against preventive maintenance, contributing to the premature deterioration of assets.

4.24 If the deterioration of roads in developing countries is to halt, all major lending agencies will have to liberalize their policies on lending for maintenance. They will also have to coordinate their policies in each

Table 4.5 External Assistance for Highways, 1981-84

Source	Amount ($Mn)	New Const., Improvements	Rehab., Reconst.	Main-tenance	Technical Assistance[a]/
		Percentage Distribution by Major Components			
IBRD/IDA	4,344	43%	34%	13%	10% a/
Other Multilateral	2,889				
Of which: ADB, AfDB, BADEA, IDB, Islam DB, OPEC Fund	(1,892)	59%	30%	10%	1% b/
Bilateral: DAC	1,529				
Of which: France, Germany, and Japan	(864)	62%	25%	8%	5%
Bilateral: Other	450	94%	5%	1%	neg.

a/ Mostly for maintenance.
b/ Self-standing technical assistance (TA); project-related TA not included.

country — rather than pursuing disparate and sometimes conflicting goals. Important in establishing the foundation for this coordination is having the various lenders agree on a comprehensive road program with the recipient country. And to ensure fiscal discipline in the long run, all parties should scrutinize the implications of such a program: the capital and current budgets, the relative priorities of different parts of the program, and the size of the program in relation to resources available from domestic and foreign sources. That should make it easier to coordinate assistance in ways that make the most effective use of resources.

4.25 Chile shows what such a coordinated program of highway sector lending can achieve (Box 4.2). The requirements will differ in each country, so the content and relative size of internal and external contributions will also differ. For countries at the hard core of the road problem, the requirements in each dimension of the problem (money, technical skills, and administrative capability) are greater than can be met without assistance. For these countries, the need for concerted action with donors is particularly great, since there is so little margin for waste.

Box 4.2

World Bank Road Sector Lending in Chile

Until 1985 World Bank lending for roads in Chile was mainly for individual construction projects. By 1985, however, the rapidly rising road maintenance requirements were already more than Chile could handle with its central funding and its decentralized institutional arrangements. Seventy percent (56,000 kilometers) of the network was the responsibility of municipal governments, which lacked the technical, managerial, and financial resources needed for the task.

On advice from the Bank the central road agency (Vialidad) decided to resume gradually the responsibility for local roads and to use private contractors wherever they were competitive. Comprehensive sector planning was introduced, using the Bank's Highway Design and Maintenance Model. The central road maintenance budget was to be increased from $78 million for 1986 to $123 million for 1988, with two-thirds of the investment budget reallocated to rehabilitation and reconstruction ($44 million a year).

To support these moves and the new 1986-88 Road Investment and Maintenance Program, the Bank provided a sector loan of $140 million (21 percent of the program). Disbursements from the loan are tied to work on maintenance to ensure timely execution of this high priority program. The Bank also participated in a parallel $400 million loan and worked with other lenders and suppliers to finance the rest of the program.

CHAPTER 5: POLICY CONCLUSIONS AND RECOMMENDATIONS

5.01 The conclusions and recommendations brought together in this chapter derive from three main considerations: the increasing rate of road deterioration, the insulation of road authorities from the consequences of poor maintenance, and the very large costs and financial requirements involved.

5.02 The dynamics of road deterioration have much to do with the road maintenance problem. Paved roads do not deteriorate at a uniform rate. During an initial phase of several years, deterioration is minor but it accelerates rapidly thereafter. Casual observation of road surfaces gives little warning of the imminence of the critical phase, when road conditions begin to deteriorate rapidly. If maintenance is neglected, road users bear the brunt of the increase in total transport costs (the sum of infrastructure and vehicle operating costs), since the share of agency costs in the total cost of transport is small. Although vehicle operating costs constitute the dominant share of total road transport costs, improvements in (uncongested) road conditions save less in vehicle operating costs than previously estimated. Project analysts, therefore, have sometimes erred by crediting road investments with greater benefits than are justified. Meanwhile, road authorities have often erred by ignoring the effect of neglected maintenance on user costs. For road paving, moreover, the two errors do not cancel each other out. Instead, they reinforce one another: paving is done before it is warranted, and then the pavements are neglected. The pavements become more and more costly to repair, leading to further neglect and premature failure.

5.03 Good choices in road management depend on many factors: climate, input prices, expected traffic flows, vehicle types and axle loads, existing road characteristics and conditions, efficiency of work execution and maintenance, available resources and the opportunity cost of capital, and attitudes toward different risks. Because these factors vary from place to place, universal prescriptions could lead to many more mistakes than successes — thus making it necessary to come up with specific solutions for each country. Some general conclusions nevertheless emerge from the empirical research of the past decade.

Road Planning and Maintenance

- Gravel roads are more economical than paved roads where traffic volumes are low, the climate is not extreme, construction materials not especially scarce, and adequate maintenance can be expected. This is true even for traffic substantially higher than the previously assumed limits for these roads. The uncertainty surrounding some of the assumptions on which a decision to pave has to be based allows a broad range of cost tradeoffs with the breakeven traffic volume for paving varying from under 100 vehicles a day to more than 400. It may, therefore, be reasonable to make decisions on grounds of prudence, taking into consideration local conditions and the reliability of future maintenance.

- Some paved roads should, according to present knowledge, have been left unpaved because they carry so little traffic. Rather than maintain such roads at normal standards, it may be economical, when funds are limited, to let them deteriorate and simply to use low-cost patching to keep them usable.

- If a road carrying more than about 500 vehicles a day is to be paved or strengthened, and if axle loads are hard to control, the economic savings from staged construction of the pavement are likely to be less than the cost of premature pavement failure. Thus, countries that have difficulty enforcing load limits should build roads to higher initial standards — even though this normally means building fewer roads.

- Because of the nonlinear deterioration pattern of paved roads, the resurfacing of newer roads can be deferred with only a small penalty — but only if those roads are not too close to their critical age and not heavily traveled. If, however, the roads are somewhat older or traffic is heavier, the deferral of resurfacing could cause irreversible breakdowns and require costly reconstruction.

- In ranking the factors affecting maintenance choices, traffic volume is generally more important than road condition. So when budgets are severely constrained, across-the-board maintenance cutbacks may not be the answer. It may be better to maintain high-volume roads in fair or good condition and to reduce substantially the maintenance of some low-volume roads.

- Because the deterioration of paved roads is so insidious, a road maintenance agency must regularly monitor the condition of roads so that maintenance will not be delayed beyond the point at which costs rise steeply. The agency must also monitor the volume and mix of traffic and axle loads to determine priorities for investment and maintenance. An effective management information system that covers these conditions as well as the agency's equipment, supplies, and personnel is a basic requirement for adequate planning and deployment of resources.

- For maximum economy, road maintenance policy should be coordinated with road design and construction planning, and the life-cycle costs of the roads should be balanced against the operating costs of the vehicles using them. This coordination requires a good data base and a capable staff using sound analytical techniques. Appropriate models and information management systems exist for such analyses. Their use does not prevent errors that result from bad data or incorrect traffic forecasts, but using the system may help avoid the errors of oversimplification.

Institutional Development

- Inadequate maintenance in developing countries has various causes, but institutional failure is the only explanation for its extent. At the heart of this failure is the absence of accountability. All activities to strengthen institutions, enhance incentives, and improve the internal workings of road agencies should be judged by their promise to increase accountability. The road agency itself should be subject to an independent system of auditing and inspection.

- The nature of road deterioration and the separation of road management from road use have sheltered road authorities from public pressures and market signals. Both user groups and highway administrations should stimulate public awareness and communicate their needs and problems to policymakers.

- To limit the potential for conflict between the planning and control function of the road authority and the work execution function, the two functions should be separated. The government should minimize its direct role in works execution, even for routine maintenance, and transfer that responsibility to independent entities operating in a competitive environment characterized by managerial flexibility and efficiency incentives.

Financing

- In countries with a backlog of roads needing rehabilitation and in those with young roads approaching the age when maintenance requirements multiply, adequate resources should be brought to bear on the maintenance problem before roads get worse. This focus often requires reallocating funds from new construction to rehabilitation and maintenance. Ways of increasing the total roads budget also should be sought, including increased user fees and taxes, possibly earmarked for rehabilitation and maintenance. For many countries, external financing will also be needed - without it the serviceable network will have to contract.

- In many countries road allocations will have to be transferred from new construction to maintenance unless the total can be increased. Where budgets for the two purposes are separate or where a single authority cannot reallocate funds within the total, road resurfacing and rehabilitation should be classed as a capital expenditure.

Bank Policy

5.04 Recommendations for Bank policy must distinguish between principles that apply to all highway lending and principles that apply to different countries according to their capacity for financing estimated maintenance needs and the capacity of their institutions. A review of information, backed by the experience of World Bank staff, suggests that countries can be placed in four main classes according to:

- The state of the road networks.
- The financial requirements for maintenance and rehabilitation and the country's ability to meet those requirements.
- The possibilities for reallocating recurrent funds for roads without major disruptions.
- The institutional capacity to absorb more funding for maintenance and rehabilitation.

5.05 The four categories are reasonably exhaustive and cover the different cases that Bank operational work is likely to encounter in the next few years (Box 5.1). Each category can be exemplified by countries for which available information appears adequate.

- Category I countries have, for the most part, used resources cost-effectively for road investments and maintenance and now have a serviceable road network. Sustaining past trends will depend on the ability of these countries to adjust their road priorities to changing circumstances and to maintain their existing institutional capacity. Provided these conditions are met and barring unforeseen events, countries in this category should suffer no serious road transport constraints over the next five to 10 years. For them, the main emphasis of external assistance should be on institutional improvements, technology transfer, and operational efficiency.
- Category II countries have underfunded road maintenance, with the result that it has been inadequate in quality or quantity, or both. They could, however, rectify past inadequacies over five to 10 years by reallocating resources to maintenance, improving the efficieny of their operations and management, securing more external assistance, and, in some cases, increasing the road budget.
- Category III countries have backlogs of rehabilitation and maintenance so large relative to domestic funds, personnel, and technology that corrective action will take substantial time, effort, and external assistance. This category is subdivided into countries in which preserving a young network is the primary need (IIIA) and countries with older networks needing massive rehabilitation (IIIB).
- Category IV countries include China and most of the Indian subcontinent. Their common characteristic is an extensive and obsolete road network in need of modernization to meet the

Box 5.1

Diagnostic Framework for External Assistance Policy in the Road Sector

CATEGORY I. In these countries, the institutional capacity and past maintenance effort have generally been adequate. They now need to adjust policies and expenditures to meet emerging maintenance requirements, particularly for new networks. They also need to devote continuing attention to institutional and technological improvements, and efficient operations.

Examples: Chile, Korea, Niger, Malawi, Yemen Arab Republic.

CATEGORY II. In these countries, the funding for maintenance has been insufficient. They urgently need to reallocate domestic and external resources within and to road sector. They also need to devote greater emphasis to policy reform to expand institutional capacity.

Examples: Kenya, Brazil, Nigeria, Indonesia, Yugoslavia.

CATEGORY III. In these countries, the institutional capacity has been grossly inadequate. They urgently need to mobilize substantial external financial and institutional assistance. They must give a high priority to the coordination of aid programs and emphasize institutional reform.

A. This subcategory of countries must give priority to resurfacing and strengthening paved and unpaved roads to preserve relatively new networks and to building institutional capacity.

Examples: Mali, Benin, Nepal, Burundi, Liberia, Senegal.

B. This subcategory of countries must give priority to restoration of aging infrastructure and to building the institutional capacity to aid economic recovery.

Examples: Laos, Ghana, Bolivia, Tanzania, Madagascar, Sierra Leone.

CATEGORY IV. In these countries, the networks and maintenance technology are obsolete. They need to mobilize domestic and external resources for modernization. They also need to place major emphasis on technology transfer, institutional improvements, and the development of skills.

Examples: China, India, Pakistan, Bangladesh.

burgeoning demand for road transport. With few exceptions, these countries have not neglected maintenance. But their aged road networks and outmoded maintenance technology seriously constrain good maintenance practice. These countries need to mobilize substantial domestic and external financial resources to meet the growing needs of their road networks.

5.05 A common requirement across all four categories, and one of major importance to Bank policy, is the reallocation of domestic and external, resources to balance new construction with maintenance, rehabilitation, and betterment. Reallocation will vary according to each country's circumstances within the broad limits for each category. In most countries, reallocating the road budget will leave fewer resources for new construction, so that new investment priorities will have to be established. In some countries, moreover, no amount of reallocation will suffice — nor will the economic situation permit additions to the road budget. In such circumstances, the network's quality and extent will have to be reduced. If such a contraction appears inescapable, the Bank's analytic work will focus on establishing priorities for essential maintenance and restoration.

5.06 The Bank's sector and economic work in transport will refine the assignment of countries to the four categories. Moreover, the analysis of a country's road sector will be a key input to Bank country assistance strategies for that sector, particularly for countries having the most critical problems. Because restoration and maintenance needs vastly exceed the resources available for this purpose in most countries, public investment and expenditure reviews will recommend the division of road expenditures between new construction, restoration, and maintenance. These reviews will also evaluate the financial and institutional capacity for coping with the future maintenance needs of new road investments and propose cost-effective investment and maintenance strategies.

5.07 Bank lending for roads will be conditional on each country's achievement of an acceptable distribution of expenditures among major purposes: new construction, restoration, and maintenance.

- For countries in Category III, lending will normally be confined to road maintenance and restoration — with the condition that the country also applies its entire road budget, including external assistance to maintenance and restoration. Exceptions to this condition, other than minor ones, will be made where development roads are needed to exploit agricultural and mineral resources in the context of identifiable investment projects.

- For countries in Category II, lending will be conditional on periodic agreement between the Government and the Bank, about the division of funds among new construction, restoration, and maintenance. Funds will be committed or released in tranches, conditional on reaching the interim obectives of agreed-on programs.

- In Bank appraisals of road construction and betterment the probability of a road being maintained to acceptable standards will enter explicitly into the calculation of a project's expected net benefits, and reflect the country's past road maintenance record.

5.08 Because so much capital is at risk and the economic outcomes are so sensitive to country differences in networks, traffic, and other circumstances, the Bank will require that road agencies have an adequate road management system — or a phased, monitorable program for establishing one. And to improve efficiency and reduce the potential for conflict between the planning and execution functions of the road authority, the Bank will encourage maintenance work by (private or public) entities outside the road authority — entities operating according to commercial principles and preferably in a competitive environment. In addition, the Bank will support schemes to increase awareness of the need for management systems and for adequate resources for rehabilitation and maintenance. These schemes will focus on efforts to educate government officials and to make the public aware of the consequences of neglecting maintenance. Such efforts will include regular publication of the data from monitoring road conditions.

5.09 The Bank will also assess progress in the education and public awareness components of Bank projects and in the transfer of maintenance work to entities outside the road agency. In addition, the Bank will periodically review the four-category classification of countries and make appropriate adjustments based on new evidence or the findings of its operational staff.

Action by the International Community

5.10 In financing highways, external agencies should emphasize rehabilitation and maintenance in countries in Categories II and III and modernization in countries in Category IV. They should limit their financing of new construction largely to countries in Categories I and IV — and then only in integrated programs for construction, maintenance, rehabilitation, and modernization. In addition, all external agencies involved in road sector activities in any country in Category II or III should require that the recipient government establish internal administrative mechanisms to coordinate and monitor external assistance programs. Consultative group or round table meetings can effectively aid governments used to achieve this objective.

5.11 The data base needed for understanding the factors that influence road deterioration and the effects of different maintenance processes should be substantially strengthened and refined. Road research institutions and highway authorities in developed and developing countries should continue research on the multi-dimensional issues of road deterioration — technical, institutional and financial — and should support international exchanges of data, information, technology, and systems. In addition, external agencies should provide technical and financial support for the compilation of international statistics on road conditions. Such a compilation is essential if worldwide trends are to be detected and reliable judgments made about the relative performance of countries. The United Nations Statistical Office — or an organization such as the Permanent International Association of Road Congresses (PIARC) or the International Road Federation (IRF) — could assume responsibility for compiling these statistics. Also recommended is the annual publication of statistics on the sources and uses of external aid for road development.

STATISTICAL TABLE A: BASIC CHARACTERISTICS OF REGIONAL ROAD NETWORKS

REGION	NUMBER OF COUNTRIES	AREA KM2 ('000)	GNP 1984 (US$bn)	POP. 1984 (Mn)	GNP/CAPITA: MEDIAN 1984 (US$)	GNP/CAPITA: GROWTH p.a.(%) 75-85	TOTAL ROAD NETWORK: LENGTH KM ('000)	TOTAL ROAD NETWORK: % PAVED	TOTAL ROAD NETWORK: DENSITY: KM PER 100KM2	TOTAL ROAD NETWORK: DENSITY: KM PER 1000P	TOTAL ROAD NETWORK: DENSITY: KM PER UNIT GNP (US$Mn.)	MAIN ROADS: NETWORK ('000KM)	MAIN ROADS: % PAVED	MAIN ROADS: DENSITY: KM PER 100KM2	MAIN ROADS: DENSITY: KM PER 1000P	MAIN ROADS: DENSITY: KM PER UNIT GNP (US$Mn.)	MAIN PAVED ROADS: LENGTH KM ('000)	MAIN PAVED ROADS: DENSITY PER 100KM2	REPLACEMENT VALUE OF MAIN NETWORK: AVG.COST/KM PAVED (US$)	REPLACEMENT VALUE OF MAIN NETWORK: AVG.COST/KM UNPAVED (US$)	VALUE (US$bn): PAVED	VALUE (US$bn): UNPAVED	VALUE (US$bn): TOTAL	% OF GNP
EASTERN AFRICA	19	11,051	51.2	201	310	-0.1	580.3	7.7	5.3	2.9	11.5	190.5	24.6	1.7	0.9	3.7	46.9	0.6	255,000	40,000	12.0	5.7	17.7	34.6
WESTERN AFRICA	20	8,891	104.7	165	290	-1.0	410.9	12.6	4.8	2.3	4.1	144.5	37.3	1.6	0.8	1.4	53.9	0.9	245,000	40,000	13.2	3.6	16.8	16.1
Excluding Nigeria	19	7,967	34.3	90	270	-0.9	322.9	10.3	4.1	3.6	9.4	115.4	27.8	1.4	1.3	3.4	32.1	0.5	245,000	40,000	7.9	3.3	11.2	32.6
EAST ASIA & PACIFIC	7	13,104	600.4	1350	710	3.6	1539.6	18.1	11.7	1.1	2.6	450.9	61.4	3.4	0.3	0.8	276.9	9.5	300,000	40,000	83.1	7.0	90.0	15.0
Excluding China	6	3,623	281.4	221	785	2.5	571.2	16.9	15.8	2.6	2.0	196.6	52.8	5.4	0.9	0.7	103.8	5.6	300,000	40,000	31.1	3.7	34.9	12.4
SOUTH ASIA	6	5,120	257.5	1008	220	2.4	1680.7	31.1	32.8	1.7	6.5	217.1	80.3	4.2	0.2	0.8	174.3	7.4	180,000	40,000	31.4	1.7	33.1	12.9
Excluding India	5	1,922	62.7	250	180	1.8	180.7	26.7	9.4	0.7	2.9	89.6	56.0	4.7	0.3	1.4	50.2	2.3	180,000	40,000	9.0	1.6	10.6	16.9
EUROPE, MIDDLE EAST AND NORTH AFRICA	14	6,476	338.1	232	1795	3.1	1051.0	29.3	16.2	4.5	3.1	303.7	74.5	4.7	1.3	0.9	226.3	10.6	280,000	40,000	63.4	3.1	66.4	19.7
LATIN AMERICA AND CARIBBEAN	19	10,059	583.9	350	1190	0.0	2212.1	11.0	11.7	6.3	3.8	511.7	49.2	2.7	1.5	0.9	251.8	6.0	260,000	40,000	65.5	10.4	75.9	13.0
Excluding Brasil and Mexico	17	8,376	199.1	141	1160	-0.1	876.1	11.8	10.4	6.2	4.4	193.7	46.3	2.3	1.4	1.6	85.6	2.0	260,000	40,000	22.3	4.3	26.6	13.4
TOTAL	85	63,581	1935.9	3327			7502.6	19.4	11.8	2.3	3.9	1818.4	56.8	2.9	0.5	0.9	1030.0	29.5			268.4	31.5	299.9	15.5

SOURCE: World Bank Surveys and Reports

STATISTICAL TABLE B: ROAD NETWORKS BY GEOGRAPHIC REGION (1984)

REGION	COUNTRY	POP. 1984 (M)	AREA ('000KM2)	GNP/CAPITA 1984	GNP/CAPITA ANNUAL GROWTH 1975-85 (%)	TOTAL GNP 1984 ($M.)	TOTAL NETWORK LENGTH (KM)	TOTAL NETWORK DENSITY PER 100KM2	TOTAL NETWORK DENSITY PER 1000	TOTAL NETWORK DENSITY PER $MnGNP	MAIN NETWORK LENGTH (KM)	MAIN NETWORK DENSITY PER 100KM2	MAIN NETWORK DENSITY PER 1000P	MAIN NETWORK DENSITY PER $MnGNP	MAIN PAVED LENGTH (KM)	MAIN PAVED CONDITION G. (%)	MAIN PAVED CONDITION F. (%)	MAIN PAVED CONDITION P. (%)	MAIN PAVED CONST./IMPROVED IN 80/84 (KM)	MAIN PAVED CONST./IMPROVED IN 80/84 (%)	MAIN PAVED CONST./IMPROVED IN 75/79 (KM)	MAIN PAVED CONST./IMPROVED IN 75/79 (%)	MAIN UNPAVED LENGTH (KM)	MAIN UNPAVED CONDITION G. (%)	MAIN UNPAVED CONDITION F. (%)	MAIN UNPAVED CONDITION P. (%)	MAIN UNPAVED CONST./IMP. 80/84 (KM)	MAIN UNPAVED CONST./IMP. 80/84 (%)
ESA	BOTSWANA	1.00	600	960	7.9	960	13,000	2.2	13.0	13.5	8,026	1.3	8.0	8.4	1,957	90	8	2	600	31	400	20	6,069	60	30	10	400	7
ESA	BURUNDI	4.60	28	220	0.9	1,012	5,600	19.3	1.2	5.3	2,900	10.4	0.6	2.9	744	50	37	5	380.00	52	40.00	5	2,156	60	25	15		
ESA	COMOROS	0.38	2	340	(1)	129	850	42.5	2.2	6.6	762	38.1	2.0	5.9	456	60	20	20	50	11	21	5	306	20	20	60		
ESA	DJIBOUTI	0.36	22	350	(1)	129	2,800	12.7	7.8	21.7	1,100	5.0	3.1		300	30	60	10	24	8			800	10	10	80		
ESA	ETHIOPIA	42.20	1,222	110	-0.9	4,642	43,200	3.5	1.0	9.3	13,600	1.1	0.3	2.9	3,600	33	34	33	405.00	12			9,000	33	34	33		
ESA	KENYA	19.60	583	310	0.1	6,076	55,000	9.4	2.8	9.1	25,300	4.3	1.3	4.2	6,000	32	52	16	1,400	23	1,600	27	19,300	66	17	17	350	2
ESA	LESOTHO	1.50	30	530	2.7	795	4,000	13.3	2.7	5.0	2,010	6.7	1.3	2.5	398	25	35	40					1,612	20	50	30		
ESA	MADAGASCAR	9.90	587	260	-3.4	2,574	50,000	8.5	5.1	19.4	10,150	1.7	1.0	3.9	4,800	20	30	50	300	6	450	9	5,350	20	20	60		
ESA	MALAWI	6.80	118	180	0.2	1,224	13,200	11.2	2.0	10.8	5,571	4.7	0.8	4.6	2,004	50	35	15	279	13	913	46	3,567	30	35	35	400	11
ESA	MAURITIUS	1.10	2	1,090	2.6	1,199	2,795	139.8	2.5	2.3	1,787	89.4	1.6	1.5	1,610								177					
ESA	RWANDA	6.00	26	280	1.9	1,624	10,000	38.5	1.7	6.2	4,000	15.4	0.7	2.5	800	80	20	0	300	38	50	8	3,200	20	80	0	3000	94
ESA	SOMALIA	5.20	638	260	-0.3	1,352	21,600	3.4	4.2	16.0	9,644	1.5	1.9	7.1	2,460	60	20	20					7,184	30	30	40		
ESA	SUDAN	21.30	2,506	360	-0.4	7,668	19,110	0.8	0.9	2.5	7,000	0.3	0.3	0.9	2,240	40	30	30	790.00	35			4,760	20	20	60		
ESA	SWAZILAND	0.71	17	800	-0.2 (0)	568	2,821	16.6	4.0	5.0	2,726	16.0	3.8	4.8	521	50	25	25	285	55	80	12	2,203	25	25	50		
ESA	TANZANIA	21.50	945	210	-1.7	4,515	53,600	5.7	2.5	11.9	17,700	1.9	0.8	3.9	3,240	30	34	36	581	18			14,460	5	47	48	1700	12
ESA	UGANDA	15.00	236	230	-3.3	3,450	27,037	11.5	1.8	7.8	5,691	2.4	0.4	1.6	1,726	10	59	31			110	6	3,965	52	26	22		
ESA	ZAIRE	29.70	2,345	140	-3.9	4,158	145,000	6.2	4.9	34.9	40,900	1.7	1.4	9.8	2,400	17	20	63	200	8	400	17	38,500	61	25	14		
ESA	ZAMBIA	6.40	753	470	-3.7	3,008	35,000	4.6	5.5	11.6	20,653	2.7	3.2	6.9	5,502	40	30	30	150	3	1,200	22	15,151	30	35	35	250	2
ESA	ZIMBABWE	8.10	391	760	-1.3	6,156	85,000	21.7	10.5	13.8	11,000	2.8	1.4	1.8	5,595	70	25	5					5,088	50	30	20	2090	39
COUNTRIES = 19																												
SUM		201.2	11,051			51,229	589,493	5.3	2.9	11.5	190,321				46,853								143,858					
AVERAGE				255	-0.1							1.7	0.9	3.1		62	32	26						62	30	28		
WA	BENIN	3.90	113	270	0.6	1,053	7,500	6.6	1.9	7.1	4,926	4.4	1.3	4.7	986	58	36	6	230	23	100	10	3,940	15	55	30	500	13
WA	BURKINA	6.60	274	160	0.9	1,056	11,300	4.1	1.7	10.6	6,200	2.3	1.0	6.0	1,400	40	40	20	400	29	201	20	4,800	10	30	60	355	7
WA	CAMEROON	9.90	475	760	3.9	7,524	64,905	13.7	6.6	8.6	13,500	2.8	1.4	1.8	2,900	60	30	10	783	27	787	27	10,600	20	50	30		
WA	CHAD	4.90	1,284	80	-7.7 (0)	392	31,300	2.4	6.4	79.8	3,000	0.2	0.6	7.7	163	4	0	96	7.00	4			3,637	8	19	73	1000	27
WA	CONGO	1.80	342	1,140	2.2	2,052	11,000	3.2	6.1	5.4	7,000	2.0	3.9	3.4	1,100	69	15	16	620	56	400	44	5,900	30	20	50	150	3
WA	C.A.R.	2.50	623	260	-1.4	650	22,600	3.6	9.0	34.8	5,250	0.8	2.1	8.1	442	36	35	29	269	61	65	15	4,808	60	15	15	955	20
WA	EQUAT. GUINEA	0.37	28	180	(1)	67	1,540	5.5	4.2	23.1	1,090	3.9	2.9		485	26	0	74			80.00	16	605	0	0	100		
WA	GHANA	12.30	239	350	-1.9	4,305	28,400	11.9	2.3	6.6	16,130	5.9	1.1	3.3	5,782	12	27	61	126	2			8,348	17	48	35		
WA	GUINEA	5.90	245	330	0.2 (0)	1,947	14,000	5.7	2.4	7.2	4,550	1.8	0.8	2.3	1,145	51	35	14	201	18	85	7	3,405	13	22	65	975	28
WA	GUINEA-BISSAU	0.88	36	180	-2.1 (0)	158	4,040	11.2	4.6	25.5	2,300	6.4	2.6	14.5	485	2	65	33	30.00	6	30.00	6	1,815					
WA	IVORY COAST	9.90	322	610	-2.2	6,039	47,000	14.9	4.8	7.9	13,680	4.2	1.4	2.3	3,620	78	15	7	955	26	1,330	37	10,060	30	60	10	170	2
WA	LIBERIA	2.10	111	470	-3.7	987	7,550	6.8	3.6	7.7	3,945	3.6	1.9	4.0	557	85	13	2	110	20	250	45	3,388	15	75	10	176	5
WA	MALI	7.30	1,240	140	0.0	1,022	13,500	1.1	1.8	13.2	5,222	0.4	0.7	5.1	1,890	43	33	25	540	29	270	30	3,332	11	4	85	1340	40
WA	MAURITANIA	1.70	1,031	450	-0.4	765	7,500	0.7	4.4	9.8	2,400	0.2	1.5	3.2	1,640	30	30	40	1,200	73	200	12	860	0	5	95		
WA	NIGER	6.20	1,267	190	-1.1	1,178	19,000	1.5	3.1	16.1	6,303	0.5	1.0	5.4	2,600	70	20	10	505	19	757	29	3,700	30	35	35	600	10
WA	NIGERIA	96.50	924	730	-3.3	70,445	108,000	11.7	1.1	1.5	29,100	3.1	0.3	0.4	21,100	62	15	23	4,920	24	7,529	36	8,000	0	10	90		
WA	SENEGAL	6.40	196	480	-1.3	3,072	11,700	6.0	1.8	3.8	9,700	4.9	1.5	3.2	3,762	51	36	13	470	12	740	20	5,938	4	26	70	400	7
WA	SIERRA LEONE	3.70	72	310	-0.8	1,147	9,924	13.8	2.7	8.7	7,000	9.8	1.9	6.1	1,280	20	45	35	240	19			5,700	30	40	30		
WA	THE GAMBIA	0.71	11	260	-1.7	185	2,300	21.7	3.4	12.9	1,209	11.0	1.7	6.5	407	27	50	23	210	47	30	7	762	30	42	28	310	81
WA	TOGO	2.90	57	250	-1.5	725	7,000	12.3	2.4	9.7	2,921	5.1	1.0	4.0	1,712	40	24	36	427	25	235	14	1,209	30	45	25	85	7
COUNTRIES = 20																												
SUM		185.5	8,891			104,789	430,837	4.8	2.3	4.1	144,512				53,505								91,007					
AVERAGE				562	-1.0							1.6	0.8	1.4		52	23	25						30	36	34		

SOURCE: World Bank Surveys and Reports
(0) 1973-83
(1) Not Available

STATISTICAL TABLE B: ROAD NETWORKS BY GEOGRAPHIC REGION (1986) (cont'd)

REGION	COUNTRY	POP. 1986 (M)	AREA ('000KM2)	GNP/CAPITA 1986	GNP/CAPITA ANNUAL GROWTH 1976-86 (%)	TOTAL GNP 1986 (M$.)	TOTAL NETWORK LENGTH (KM)	TOTAL NETWORK DENSITY PER 100KM2	TOTAL NETWORK DENSITY PER 1000P.	TOTAL NETWORK DENSITY PER $MnGNP	MAIN NETWORK LENGTH (KM)	MAIN NETWORK DENSITY PER 100KM2	MAIN NETWORK DENSITY PER 1000P	MAIN NETWORK DENSITY PER $MnGNP	MAIN PAVED LENGTH (KM)	CONDITION G. (%)	CONDITION F. (%)	CONDITION P. (%)	CONST./IMPROVED IN 80/86 (KM)	80/86 (%)	75/79 (KM)	75/79 (%)	MAIN UNPAVED LENGTH (KM)	CONDITION G. (%)	CONDITION F. (%)	CONDITION P. (%)	CONST./IMP. 80/86 (KM)	80/86 (%)
EMENA	ALGERIA	21.20	2,382	2,610	3.2	51,882	78,190	3.3	3.7	1.5	38,347	1.7	1.9	0.8	32,480	40	32	28			1,870	3	6,067	25	50	25		
EMENA	CYPRUS	0.67	9	3,590	7.0	2,405	6,831	73.9	10.2	2.8	3,031	33.7	4.5	1.3	2,938	38	38	24	253	9	480	16	93	0	50	50		
EMENA	EGYPT	48.50	1,001	720	4.8	33,068	30,089	3.0	0.7	0.9	28,725	2.9	0.6	0.9	15,081	39	33	28					13,644					
EMENA	HUNGARY	10.70	93	2,100	5.1 (*)	22,470	130,185	140.6	12.9	6.1	24,000	25.8	2.2	1.1	24,000								0					
EMENA	MOROCCO	21.60	447	670	1.4	14,338	57,692	12.9	2.7	4.0	19,080	4.3	0.9	1.3	14,816	20	44	36	1,625	11	55	0	4,264					
EMENA	OMAN	1.10	300	6,480	4.4 (*)	7,130	18,123	6.0	16.5	2.5	8,474	2.8	7.7	1.2	3,292	66	20	14	1,950	59	900.00	27	5,182				690	13
EMENA	PORTUGAL	10.20	92	1,970	1.6	20,094	52,031	56.6	5.1	2.6	18,631	20.7	1.9	0.9	17,900	50	30	20	1,400	8	1,082	6	1,131	40	40	20	280	16
EMENA	ROMANIA	22.70	238	2,290	(1)	51,983	73,900	30.9	3.2	1.4	14,788	6.2	0.6	0.3	14,080	69	21	10	810	6	1,678	12	700	35	37	24		
EMENA	SYRIA	10.10	185	1,620	-0.2	16,362	26,200	14.2	2.6	1.6	15,700	8.5	1.6	1.0	11,700								4,000					
EMENA	TUNISIA	7.00	164	1,270	2.6	8,890	78,190	47.7	11.2	8.8	16,900	10.3	2.4	1.9	9,140	55	36	9	1,000	11	900	10	7,760	30	40	30	2300	30
EMENA	TURKEY	48.40	781	1,160	1.4	56,144	329,193	42.2	6.8	5.9	60,953	7.8	1.3	1.1	38,469								22,584					
EMENA	YEMEN AR	7.80	195	550	4.0	4,290	25,020	12.8	3.2	5.8	3,028	1.6	0.4	0.7	2,068	70	20	10	450	22	300	15	980	40	30	30	210	21
EMENA	YEMEN PDR	2.00	333	550	5.2	1,100	7,100	2.1	3.6	6.5	1,887	0.6	0.9	1.7	1,650	27	69	4	637	39	602	36	237	33	33	34		
EMENA	YUGOSLAVIA	23.00	256	2,120	2.6	48,760	130,000	50.8	5.7	2.7	48,880	19.1	2.1	1.0	36,630	30	41	29	1,358	4	441	1	12,250	30	50	20		
COUNTRIES = 14																												
SUM		232	6,676			338,115	1,050,952	16.2	4.5	3.1	303,736				226,124								79,612					
AVERAGE				1,636	3.1							4.7	1.3	0.9		41	35	24						30	46	24		
LAC	ARGENTINA	30.10	2,767	2,230	-1.9	67,123	212,306	7.7	7.1	3.2	35,505	1.3	1.2	0.5	27,056	35	21	44			2,200	8	8,449	20	40	40		
LAC	BARBADOS	0.25	0	4,340	1.6	1,128	1,670	388.4	6.6	1.5	1,367	317.9	5.3	1.2	1,367								0					
LAC	BELIZE	0.16	23	1,150	3.6 (*)	184	2,000	8.7	12.5	10.9	1,871	8.1	11.7	10.2	442	32	48	20					1,429	2	43	55		
LAC	BOLIVIA	6.20	1,099	540	-4.0	3,348	39,824	3.6	6.4	11.9	9,382	0.9	1.5	2.8	1,351	21	48	31	120	9			8,031	20	30	50		
LAC	BRAZIL/FEDERAL	132.60	8,512	1,720	1.2	228,072	1,316,343	15.5	9.9	5.8	64,642	0.8	0.5	0.3	45,291	30	42	28	6,570	15			19,351	30	42	28		
LAC	BRAZIL/STATES										162,596				55,807				8,000	14	8,000	14	106,789					
LAC	CHILE	11.80	757	1,700	0.9	20,060	79,089	10.4	6.7	3.9	22,831	3.0	1.9	1.1	8,964	33	56	11	630	7	750	8	13,867	7	75	18	500	4
LAC	COLOMBIA	28.40	1,139	1,390	1.7	39,476	77,280	6.8	2.7	2.0	24,397	2.1	0.9	0.6	9,620	42	37	21	1,730	18	1,853	28	14,777	42	37	22	1150	8
LAC	COSTA RICA	2.50	51	1,190	-0.3	2,975	28,500	55.9	11.4	9.6	4,789	9.4	1.9	1.6	3,044	22	29	49	890	29	240	8	1,745	8	7	85		
LAC	DOMINICAN R.	6.10	49	970	0.2	5,917	17,280	35.1	2.8	2.9	3,475	7.1	0.6	0.6	2,485	52	10	38	800	32	200	8	990	0	22	78	200	20
LAC	ECUADOR	9.10	284	1,150	0.3	10,465	37,910	13.3	4.2	3.6	8,400	3.0	0.9	0.8	3,380	53	19	28	270	8	790	23	5,020	65	10	25		
LAC	GUATEMALA	7.70	109	1,160	-3.3	8,932	18,428	16.9	2.4	2.1	10,641	9.8	1.4	1.2	3,043	7	50	43	243	8	162	5	7,598	11	62	27		
LAC	HAITI	5.40	28	320	0.7	1,728	4,000	14.3	0.7	2.3	2,473	8.8	0.5	1.4	606	0	100	0	130	21	130	21	1,867	10	42	48		
LAC	HONDURAS	4.20	112	700	0.4	2,940	12,050	10.8	2.9	4.1	6,018	5.4	1.4	2.0	1,614	50	43	7			282	17	4,404	50	38	12		
LAC	JAMAICA	2.20	11	1,150	-4.0	2,530	17,700	160.9	8.0	7.0	4,750	43.2	2.2	1.9	4,365	10	73	17	222	5	64	1	385	1	56	43	254	66
LAC	MEXICO/FEDERAL	76.80	1,973	2,040	0.6	156,672	212,626	10.8	2.8	1.4	43,500	2.2	0.6	0.3	40,520	85	10	5	4,000	10	2,000	5	2,980	30	50	20		
LAC	MEXICO/STATES										47,300				24,200								23,100					
LAC	PANAMA	2.10	77	1,980	1.3	4,158	8,655	11.3	4.1	2.1	8,400	10.9	4.0	2.0	3,094	36	54	10	330	11	450	15	5,306	8	68	24		
LAC	PARAGUAY	3.30	407	1,240	3.7	4,092	24,329	6.0	7.4	5.9	11,241	2.8	3.4	2.7	1,695	73	22	5	340	20	470	28	9,546	44	38	18	700	8
LAC	PERU	18.20	1,285	1,000	-2.5	18,280	58,516	4.6	3.2	3.2	27,300	2.1	1.5	1.5	7,178	24	24	52	820	11	70	1	20,122	10	30	60		
LAC	URUGUAY	3.00	176	1,980	-1.0	5,940	49,813	28.3	16.6	8.4	9,813	5.6	3.3	1.7	6,445	26	59	15					3,368	0	75	25		
COUNTRIES = 19																												
SUM		350	18,859			583,940	2,310,085	11.8	6.3	3.8	511,891				251,687								260,044					
AVERAGE				1,668	-0.03							2.7	1.5	0.9		44	32	24						24	43	33		
ALL REGIONS																												
COUNTRIES = 85																												
SUM		3,328	63,581			1,935,939	7,512,387				1,818,491				1,025,756								782,735					
AVERAGE				582								2.9	0.6	0.9		32	42	25						31	36	33		

SOURCE: World Bank Surveys and Reports
(*) 1973-83
(1) Not Available

STATISTICAL TABLE B: ROAD NETWORKS BY GEOGRAPHIC REGION (1984) (cont'd)

REGION	COUNTRY	POP. 1984 (M)	AREA ('000KM2)	GNP/CAPITA 1984	GNP/CAPITA ANNUAL GROWTH 1975-85 (%)	TOTAL GNP 1984 (US$M.)	TOTAL NETWORK LENGTH (KM)	TOTAL NETWORK DENSITY KM PER 100KM2	TOTAL NETWORK DENSITY KM PER 1000 POP	TOTAL NETWORK DENSITY KM PER $M GNP	MAIN NETWORK LENGTH (KM)	MAIN NETWORK DENSITY KM PER 100KM2	MAIN NETWORK DENSITY KM PER 1000P	MAIN NETWORK DENSITY KM PER $M GNP	MAIN PAVED LENGTH (KM)	MAIN PAVED CONDITION G. (%)	MAIN PAVED CONDITION F. (%)	MAIN PAVED CONDITION P. (%)	CONST./IMPROVED IN 80/84 (KM)	CONST./IMPROVED IN 80/84 (%)	CONST./IMPROVED IN 75/79 (KM)	CONST./IMPROVED IN 75/79 (%)	MAIN UNPAVED LENGTH (KM)	MAIN UNPAVED CONDITION G. (%)	MAIN UNPAVED CONDITION F. (%)	MAIN UNPAVED CONDITION P. (%)	CONST./IMP. 80/84 (KM)	CONST./IMP. 80/84 (%)
EAP	CHINA	1029.20	9,561	310	6.6	319,052	915,100	9.6	0.9	2.9	254,300	2.7	0.2	0.8	173,000	10	70	20	22,000	13	59,000	34	81,300	50	25	25		
EAP	INDONESIA	158.90	1,919	540	3.6	85,806	201,280	10.5	1.3	2.3	45,800	2.4	0.3	0.5	27,550	30	30	40	5,530	20	5,000	18	18,250	22	47	31	3500	10
EAP	KOREA	40.10	98	2,110	6.6	84,611	54,000	55.1	1.3	0.6	23,481	24.0	0.6	0.3	9,928	70	25	5	3,060	30	1,926	19	13,553	60	20	20		
EAP	MALAYSIA	15.30	330	1,980	4.1	30,294	45,000	13.6	2.9	1.5	25,324	7.7	1.7	0.8	23,479								1,845					
EAP	PAPUA N GUINEA	3.60	462	710	-0.6	2,616	18,565	4.0	5.5	7.1	3,652	0.8	1.1	1.5	726	34	45	21	110	15	100	35	2,926	23	71	6		
EAP	PHILIPPINES	53.40	300	660	0.1	35,244	155,663	51.9	2.9	4.4	53,864	18.0	1.0	1.5	14,192	31	54	15	900	6	500	4	39,672	25	50	25	1055	3
EAP	THAILAND	50.00	514	860	3.9	43,000	150,000	29.2	3.0	3.5	44,534	8.7	0.9	1.0	28,000	50	29	20	8,500	31	5,262	19	16,534	45	30	25		
COUNTRIES = 7																												
SUM		1,350	13,184			600,621	1,539,614	11.7	1.1	2.6	450,955				276,875								170,080					
AVERAGE				445	3.6							3.4	0.3	0.8		20	59	21						41	34	25		
SA	BANGLADESH	98.10	144	130	1.7	12,753	15,000	10.4	0.2	1.2	10,900	7.6	0.1	0.9	6,210	15	40	45	1,100	19	60	1	4,690	10	40	50		
SA	BURMA	36.10	677	180	3.9	6,496	27,983	4.1	0.8	4.3	25,400	3.8	0.7	3.9	8,400	0	50	50					17,000	0	50	50		
SA	INDIA/NATIONAL	768.20	3,288	260	1.9	194,792	1,506,000	45.6	2.0	7.7	32,000	1.0	0.0	0.2	31,600	20	45	35	2,500	8	3,000	9	400	20	40	40		
SA	INDIA/STATES										95,500				91,200	20	45	35					4,300	20	40	40		
SA	NEPAL	16.10	141	160	0.7	2,576	7,150	5.1	0.4	2.8	5,545	3.9	0.3	2.2	2,500	40	35	25	584	23	376	15	3,045	15	45	40	300	10
SA	PAKISTAN	92.40	804	380	3.3	35,112	107,673	13.4	1.2	3.1	38,830	4.8	0.4	1.1	24,142	18	50	32	1,940	8	2,590	10	14,688	5	25	70		
SA	SRILANKA	15.90	66	360	3.2	5,724	25,500	38.6	1.6	4.5	8,900	13.5	0.6	1.6	8,900	10	40	50	50	1	100	1	0	0	0	0		
COUNTRIES = 6																												
SUM		1,088	5,120			257,455	1,683,306	32.8	1.7	6.5	217,076				172,952								44,124					
AVERAGE				255	2.4							4.2	0.2	0.8		19	45	36						6	39	55		

SOURCE: World Bank Surveys and Reports

Statistical Table C: Road User Taxes: Their Structure and Contribution to Government Revenues in Selected Countries

Country	Year	Taxes on vehicle acquisition: Import	Taxes on vehicle acquisition: Purchase	Taxes on vehicle acquisition: Registn	Annual taxes on ownership: Cars	Annual taxes on ownership: Other Vehicles	Annual taxes on ownership: Drivers' Licences	Taxes on use: Fuel & Oil: Gasoline	Taxes on use: Fuel & Oil: Diesel	Taxes on use: Tires, spare parts	Taxes on use: Tolls & road transp.	Total	Total RUC as % of: Expendi-tures on roads	Total RUC as % of: Total Govt. revenues	Taxes on Income, Profits & Cap. Gains as % of total Revenues
		(as percent of total road user charge revenues)													
ESA															
Kenya	81	22	15	..	---7---		1	---55---		..	..	100	118	12	29
Madagascar	81	---35---		..	---6---		..	---59---		..	..	100	..	16	16
Mauritius	81	20	..	1	---12---		..	45	12	9	..	100	1,700	13	18
Rwanda	84	18	..	1	---11---		..	---41---		12	12	100			
Somalia	79	NA	..	4	---NA---		..	49	51	..	..	100*	|105|	|11b/|	6
Sudan	81	27	..	..	---2---		..	---33---		21	4	100	269	8c/	16d/
Uganda	84	NA	..	..	---NA---		..	---81---		..	19	100*	|411|	|12|	7
Zimbabwe	83/4			---36---			..	58	9	..	..	100	345	14	62
WA															
Cameroon	78	57	..	..	---2---		..	---28---		12	..	100	273	14	14
Sierra Leone	79	35	..	..	---11---		..	---56---		..	..	100	200	7	24
EAP															
Indonesia	85/6	11	9	14	---12---		..	50	1	e/	3	100	110	5-6f/	74
Korea	83	NA	12	4	---16---		..	30	23	..	15	100*			
Philippines	81	NA	NA	..	---11---		..	---87---		..	..	100*	|116|	|15|	22
Thailand	79	NA	26	..	---10---		..	---61---		1	..	100*	|174|	|14|	18
SA															
India	80/1	---13---			---18---		..	---45---		12	12	100	197	15	18
Pakistan	84/5	---25---		2	5	6	..	41	10	10	1	100	292	11	15
EMENA															
Oman	83	36	..	17	---..---		2	---45---		..	..	100	100	10	26
Turkey	83		---40---		---4---		..	---35---		e/	1	100			
Yemen AR	82	55	20	0	---7---		2	---16---		..	..	100	103	12	12
LAC															
Argentina	83		---11---		---14---		..	56	13	6	..	100	137	6	4
Brazil	83	NA	NA	..	---22---		..	---65---		..	12	100*		|4g/|	15
Chile	84	35	..	6	---..---		..	---55---		..	4	100	326	14	11
Dominica	80/1	---19---			---13---		..	---37---		12	..	100	..	15	17
Haiti	80	25	..	..	---9---		1	---56---		8	..	100			
Peru	80	27	..		---4---		..	---66---		..	4	100	156	5	27
Industrialized countries															
Australia	77/8	NA	NA	11	---4---		..	---58---		..	4	100*			
Canada	77	NA	NA		---29---			---71---		..	..	100*			
FR Germany	78	NA	NA		---24---		..	---76---		..	..	100*			
Gt. Britain	78	..	14		---23---		..	50	13	..	..	100*	|285|	|8|	40
New Zealand	78/9	12	29	7	..	8	..	---44---		..	..	100	204	9	65
USA	78		---28---				..	---72---		e/	1	100			

NA = not available (thought to be significant)
.. = no information (thought to be zero or insignificant)
* = total thought to be incomplete
| |= incomplete

a) 1980 data
b) 1979 RUC as % of 1978 total revenues
c) 1981 RUC as % of 1982 total revenues
d) 1982 data

e) included with taxes on vehicle acquisition
f) estimate
g) RUC exclude VAT

Sources:

Developing countries: World Bank appraisal reports and IMF Government Finance Statistics Yearbook.
Industrialized countries: Australian Bureau of Transport Economics, "Road Financing in Selected Countries," Occasional Paper 49, Canberra 1982.

ROAD DETERIORATION IN DEVELOPING COUNTRIES

Exploring Cost-Effective Options for Road Investment and Maintenance 1/

The Analytical Framework

1. The analytical framework for the technical findings is the World Bank study on highway design and maintenance standards [6, 27, 29] and the operational Highway Design and Maintenance Model (HDM) developed from it (now in its third version, HDM-III). The model enables investigators to apply the results of empirical research on underlying physical and economic relationships to evaluate policies, standards, and programs of road construction and maintenance. [42] The general relationships among the main variables in the road deterioration cycle are shown schematically in Box A1. The model contains statistically validated empirical relationships that are used to simulate most of these effects. Using data on existing roads and their conditions and estimates of future traffic volume and composition, the model predicts the deterioration of roads and the effects of specified road maintenance and improvement policies. The model then estimates the cumulative effects of these processes on road condition, particularly road roughness (one of several road condition parameters estimated by the model), which has a major effect on the operating costs of vehicles using the roads.

2. The model permits the evaluation of several maintenance alternatives for a road link, a group of roads with similar characteristics, or an entire network of paved and unpaved roads. The model computes the aggregate costs of carrying out specified maintenance and construction policies, the associated vehicle operating costs, and the time streams of total life-cycle costs discounted at several rates to find net present values or internal rates of return. Using these decision criteria, optimal combinations of road design and maintenance policies are ascertained. Maintenance policies under budget constraints are found by linking the HDM-III Model to its companion Expenditure Budgeting Model (EBM), which employs dynamic programming to deal with multiperiod resource constraints.

3. Vehicle operating costs constitute a large share (75 percent to 95 percent) of the total road transport cost, except when the traffic volume is extremely low. Thus the effect on total transport cost of even a small percentage change in vehicle operating costs is large relative to the effect of changes in construction and maintenance costs. Before the HDM studies,

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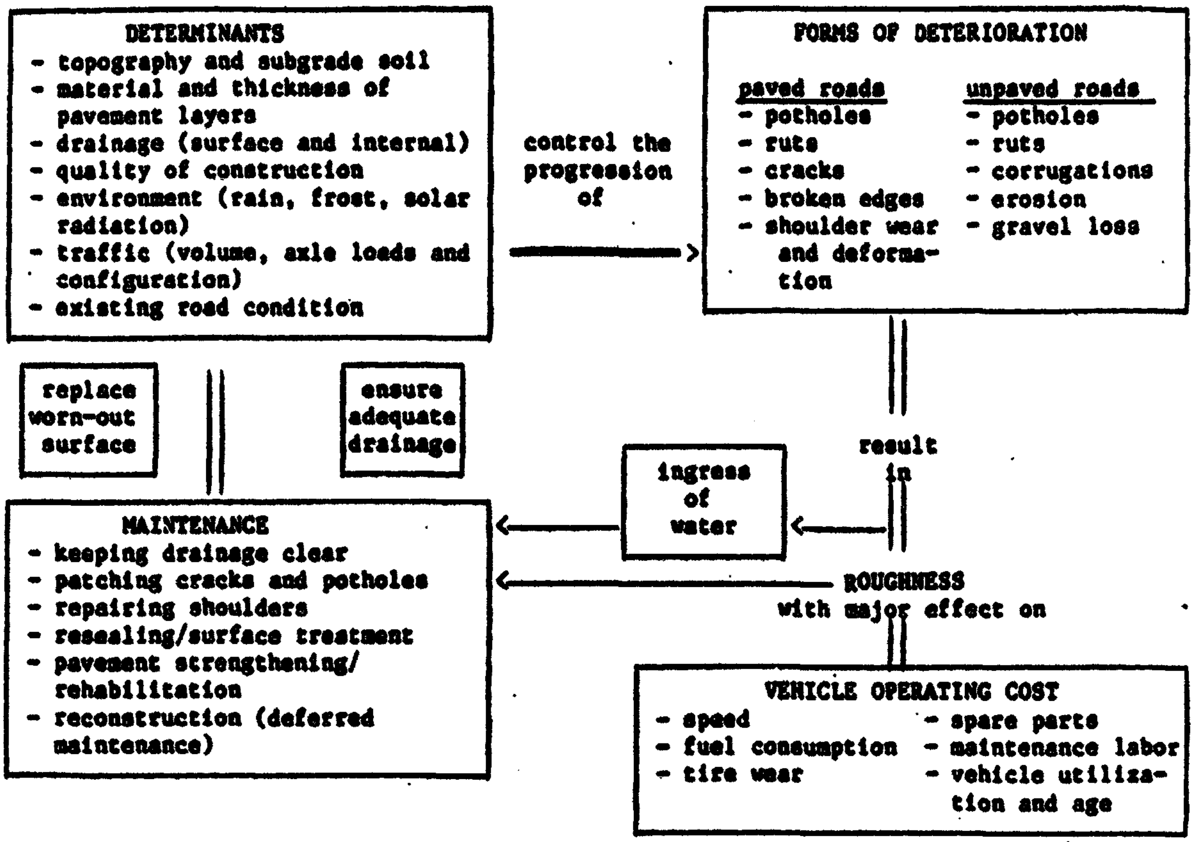
1/ This annex presents a fuller technical explanation of the findings reported in the main text on road investment and maintenance options and their economic consequences. It is based on an investigation of the engineering-economic aspects of road deterioration by Bhandari et al. [4].

Box A1

THE ROAD DETERIORATION CYCLE



<u>Unpaved roads</u>: In the absence of maintenance, unpaved roads deteriorate very rapidly, resulting in very high levels and rapid growth of roughness. The progression of roughness, however, is essentially linear, and the consequences of poor maintenance become apparent immediately. The action of traffic causes corrugations and rutting and, combined with rainfall, results in deeper ruts, potholes, and even gullies and washouts. Excessive water reduces load-bearing capacity, inducing rapid deterioration under traffic. In very dry conditions, evaporation of water reduces the bond within the surface material, which then disintegrates under traffic, so that the fine binding particles are lost in dust, leaving loose gravel, which needs periodic replenishment. The wear and tear on roads by traffic is thus strongly interrelated with climatic factors. Topography and and road alignment are significant factors because erosion, vehicle cornering, and hill climbing tend to increase gravel displacement. The condition of gravel and earth roads is highly sensitive to the level and frequency of maintenance.

<u>Paved roads</u>: The progression of deterioration on paved roads follows a distinctly nonlinear path. A long initial phase, lasting up to two-thirds of the life-cycle, passes with little discernable distress and minimal maintenance needs but is followed by a phase of accelerating deterioration (primarily in the form of cracking and rutting) resulting in increased roughness and, in extreme cases, potholing. In the absence of a major maintenance intervention this eventually leads to structural failure. While cracking causes a generalized reduction in pavement strength, this effect is exacerbated by inadequate drainage and shoulder maintenance, as rain water penetrates the cracks and weakens the underlying layers. Pavement damage due to poor drainage is particularly pronounced in wet climates and in areas subject to freezing. In one case studied here, heavy rainfall (150mm/month) reduced pavement life by about 30 percent (i.e., from 14 years to 10) compared with light rainfall (20 mm/month). Pavement deterioration is critically influenced by traffic level and loading, with damage increasing exponentially with axle load; the damage, however, may be curtailed by increasing pavement strength in terms of its structural number (SN). Based on typical examples in this study (pavements with an initial SN of 1.5 to 2.0, and 0.25 to 0.45 million standard axle loads a year), doubling the initial strength postponed the need for an overlay by 10 to 12 years.

no basic empirical data on the relationship between vehicle operating costs and pavement surface condition were available. Road investment decisions were guided by imprecise and fragmentary estimates of vehicle operation costs related primarily to the type of road (paved, gravel, earth). Based on improved estimation of vehicle speeds (in a free-flowing traffic regime) and operating costs, as a function of road design characteristics, the HDM research suggests that vehicle operating costs are somewhat less sensitive to changes in road condition than previously estimated. A comparison of vehicle operating cost indices for paved and gravel roads shows significant differences between HDM results and estimates from two earlier standard works (Table A1).

4. The relatively lower vehicle operating cost differences estimated from HDM relationships may be attributable in part to improvements in vehicle design over the last 20 years. Nevertheless it is fairly clear that certain road improvements may have smaller benefits (vehicle operating costs savings) than previously estimated. Inadequacies in empirical information on basic road deterioration and vehicle operating cost relationships in the past may have contributed to premature paving of roads, particularly in the low-traffic, high-cost African environment, and possibly to the underdesign of heavily-trafficked national roads in India, Indonesia, Nigeria, and Pakistan.

Table A1 Comparison of Vehicle Operating Cost Indices for Paved and Gravel Roads by Vehicle Class

	Passenger Car		Light Truck		Heavy Truck		Articulated Truck	
	Paved	Gravel	Paved	Gravel	Paved	Gravel	Paved	Gravel
de Weille (1966)[a]/	100	126-133	100	141-152	100	140-170	100	150-170
AASHTO (1977)[b]/	100	108-163	100	109-156	100	112-158	100	113-161
HDM (1985)[c]/	100	108-126	100	114-138	100	117-146	100	115-144

a/ Based on de Weille - Quantification of Road User Savings, Table 11, pp 28-29 [10].

b/ Based on Winfrey - Economic Analysis of Highways, Table A-44, pp 727 [43].

c/ Based on HDM relationships applied to Costa Rica data, with steady-state roughness on gravel road, ranging from an IRI of 5 to 9.

Case Studies

5. The HDM-III and EBM models were employed in a series of case studies to investigate optimal investment and maintenance policies under a variety of conditions. Road types and conditions, traffic, climate, and unit costs in the studies corresponded to those observed in three countries -- Mali, Chile, and Costa Rica. Despite the limited inferences possible from the case studies, the consistency of the results permits generalizations for wider application.

6. Thirty-one maintenance policy alternatives were tested for paved roads and ten for unpaved roads. The policies consisted of different maintenance packages with specifications of the deterioration levels at which they would be applied. The pavement maintenance options ranged from low-cost pothole patching, through bituminous resealing of the entire surface and more costly asphalt concrete overlaying, to major rehabilitation and reconstruction of the base and the surface. (See Box A2 for a classification of road improvement and maintenance works.) As a benchmark against which to measure differences in the costs of other alternatives, a "null case" was defined that included only the basic routine maintenance activities (drainage clearing, minimal vegetation control, and shoulder repair) that are also included in the other alternatives. Table A2 summarizes the alternatives, identifying each by a code (such as AL18), which will be used later in discussing the results. To illustrate, under alternative AL18, 100 percent of potholes would be patched each year, a surface treatment would be applied whenever 25 percent of the area was visibly damaged, and a 40-millimeter (mm) overlay would be applied whenever roughness reached a level of 5 on the International Road Roughness Index (IRI) scale.

7. The roads in each country's network were grouped into broadly homogeneous classes according to surface type, condition in the initial year of the study, and traffic volume. For each class, road deterioration and maintenance activity over a 30-year period were simulated under various maintenance alternatives. Road maintenance costs and vehicle operating costs were computed, discounted to the initial year, and subtracted from costs for the null case, giving the net present value for each alternative relative to the null. From these results, the best strategy for different levels of available funds and discount rates was determined for each road class. The results for different road classes were combined with the aid of the Expenditure Budgeting Model to find optimal network strategies, costs, and benefits under conditions of no budget constraint and also under varying levels and time periods of overall budget constraints. The detailed results from the case studies were used to explore cost-effective road investment and maintenance options. The main findings relate to the following factors:

- Selection of cost-effective maintenance policies.
- Optimization of maintenance expenditures under budget constraints.
- Decision criteria for pavement strength.
- Economic traffic thresholds for paving gravel roads.
- Impact of overloading.

Box A2

A Classification of Road Maintenance and Improvement Works

Routine Maintenance. Localised repair of roadway and pavement, grading of unpaved surfaces and shoulders, regular maintenance of road drainage, side slopes, verges, traffic control devices, and furniture; roadside cleaning, vegetation and dust control, snow or sand removal, and maintaining rest areas and safety appurtenances. Typical costs range from less than $300 to over $5,000 per km.

Resurfacing. Resealing a paved road or regraveling an unpaved road to preserve its structural integrity and ride quality. A paved road normally needs resurfacing at the transition from "good" to "fair" condition, provided the volume of traffic justifies retaining it in good condition. Resurfacing is sometimes called "periodic maintenance," even though all maintenance activities are periodic. Costs can vary from under $8,000 to over $40,000 per km.

Rehabilitation. Selective repair, strengthening, and shape correction of pavement or roadway (including minor drainage improvements) to restore structural strength and ride quality. The term strengthening is sometimes used to describe a specific category of pavement rehabilitation involving the application of overlays. Costs of rehabilitation can vary from under $30,000 per km for unpaved roads to over $200,000 per km for paved roads. The costs for paved roads, however, rise steeply as a pavement deteriorates from fair to poor condition.

Reconstruction. Renewal of road structure using for the most part existing earthworks and road alignment to remedy the consequences of prolonged neglect of maintenance or where rehabilitation is no longer technically possible. Costs are quite variable, ranging from about $45,000 to over $300,000 per km.

Restoration. A generic activity encompassing major rehabilitation and reconstruction works.

Betterment. Road improvements related to the width, alignment, curvature, or gradient of road (including associated rehabilitation or resurfacing works) to enhance traffic capacity, speed, or safety. Betterment works are not considered maintenance activities except for ancillary road rehabilitation or resurfacing operations. Costs are highly variable depending on the geometric improvements.

New construction. Construction of a paved or an engineered gravel or earth road on a new alignment; upgrading of a gravel or earth road to paved standard; provision of additional lane capacity; or construction of an additional carriageway, frontage roads, grade-separated interchanges, or a multilane divided highway. Costs of new construction can vary from under $50,000 per km for a gravel road to over $1,000,000 per km for a four-lane access-controlled divided highway.

TABLE A2 Maintenance Policy Alternatives for Paved and Unpaved Roads [a]

A. PAVED ROADS

ALTERNATIVE NUMBER	PATCHING (% AREA OF POTHOLES)	RESEALING	OVERLAY	RECONSTRUCTION
AL00 (Null)	0			
AL01	50			
AL02	100			
AL03	0			REC ST AT 8.5 IRI
AL04	50			REC ST AT 8.5 IRI
AL05	100			REC ST AT 8.5 IRI
AL06	100	ST AT 75% Area Damaged [b]		
AL07	100	ST AT 50% Area Damaged		
AL08	100	ST AT 25% Area Damaged		
AL09	100	ST AT 75% Area Damaged		REC ST AT 8.5 IRI
AL10	100	ST AT 50% Area Damaged		REC ST AT 8.5 IRI
AL11	100	ST AT 25% Area Damaged		REC ST AT 8.5 IRI
AL12	100		40 mm AT 5 IRI	
AL13	100		40 mm AT 4.2 IRI	
AL14	100		40 mm AT 3.5 IRI	
AL15			IMM OVERLAY (80 mm) + ALT 12	
AL16			IMM OVERLAY (80 mm) + ALT 13	
AL17			IMM OVERLAY (80 mm) + ALT 14	
AL18	100	ST AT 25% Area Damaged	40 mm AT 5 IRI	
AL19	100	ST AT 50% Area Damaged	40 mm AT 3.5 IRI	
AL20				IMM REC ST + AL12
AL21				IMM REC ST + AL13
AL22				IMM REC ST + AL14
AL23	0			REC AC AT 8.5 IRI
AL24	50			REC AC AT 8.5 IRI
AL25	100			REC AC AT 8.5 IRI
AL26	100	ST AT 75% Area Damaged		REC AC AT 8.5 IRI
AL27	100	ST AT 50% Area Damaged		REC AC AT 8.5 IRI
AL28	100	ST AT 25% Area Damaged		REC AC AT 8.5 IRI
AL29				IMM REC AC + AL12
AL30				IMM REC AC + AL13
AL31				IMM REC AC + AL14

B. UNPAVED ROADS

ALTERNATIVE NUMBER	BLADING FREQUENCY	SPOT REGRAVELING	GRAVEL RESURFACING
AL00 (Null)	None	None	None
AL01	Once a Year	30% of Material Loss	None
AL02	Every 8000 Veh. Passes	"	None
AL03	Every 6000 Veh. Passes	"	None
AL04	Every 4000 Veh. Passes	"	None
AL05	Every 2000 Veh. Passes	"	None
AL06-AL10	Same as AL01-AL06 but with Gravel Resurfacing		150 mm whenever thickness < 50 mm

[a]/ All alternatives include basic routine maintenance such as drainage clearing, minimal vegetation control, repair of shoulders and drains.

[b]/ Damaged area constitues the area of pavement surface with specific signs of distress and visible defects.

Terminology: ST = bituminous surface treatment
AC = asphalt concrete
REC = reconstruction with either ST or AC surface
IMM = immediate (i.e., first year of the analysis period)
IRI = International Roughness Index

Selection of Cost-Effective Maintenance Policies

8. The choice and staging of maintenance operations on paved and unpaved roads are strongly affected by the differences in their deterioration characteristics. On unpaved roads, the linear but rapid path of deterioration requires special attention to routine maintenance, particularly the frequency of blading. The nonlinear deterioration characteristics of paved roads offer more options for the choice and timing of maintenance.

9. To identify cost-effective road maintenance policies for paved roads, particularly under budget constraints, the trade-off between agency and user costs was examined. To illustrate, Figure A1 shows the results of such an analysis, covering 21 maintenance alternatives for low-volume paved roads in good to fair condition in Mali (average daily traffic of 400 vehicles).2/ Maintenance alternatives and their specifications are identified in this and other graphs by the codes in Table A2. The bar chart (Figure A1-A) shows the present value, discounted at 12 percent, of the net cost savings relative to the null case. To arrive at net cost savings, the increase in maintenance and construction costs incurred by the road agency is subtracted from the difference in vehicle operating cost. In most cases this yields a positive saving, but alternatives AL15, AL16, and AL17 (involving immediate application of a thick overlay) and alternatives AL20, AL21, and AL22 (involving immediate reconstruction) cost more than the benefits they yield when discounted at 12 percent.

10. Net present value, discounted at 12 percent, is maximized by strategy AL12 (patching all potholes annually and applying a 40-mm overlay whenever pavement roughness exceeds 5 IRI). But several other alternatives with very different combinations of vehicle operating costs and road agency expenditures, are almost as good by this measure. This finding is important because it widens the room for maneuver when agencies are subject to budget constraints. For example, the curve in Figure A1-B relating agency expenditures to vehicle operating costs for selected alternatives shows that AL05 (pothole patching until roughness reaches an IRI of 8.5, then reconstruction) entails about half the road agency expenditure of alternative AL12, while vehicle operating costs are higher by about $1.10 for each agency dollar saved — a net loss of only $.10 per $1.00 of reduction in agency expenditure. If funds are limited, this may be an attractive option.

11. The net present value of total transport costs for different levels of agency expenditures is illustrated in Figure A2 for four cases. The most efficient maintenance alternatives lie on the positively sloped segment of the outer boundary — the "efficiency frontier." Alternatives represented by points inside the frontier are always inferior to a

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2/ Results proved to be identical for some pairs of the 31 alternatives; for such cases only one of the pair is graphed.

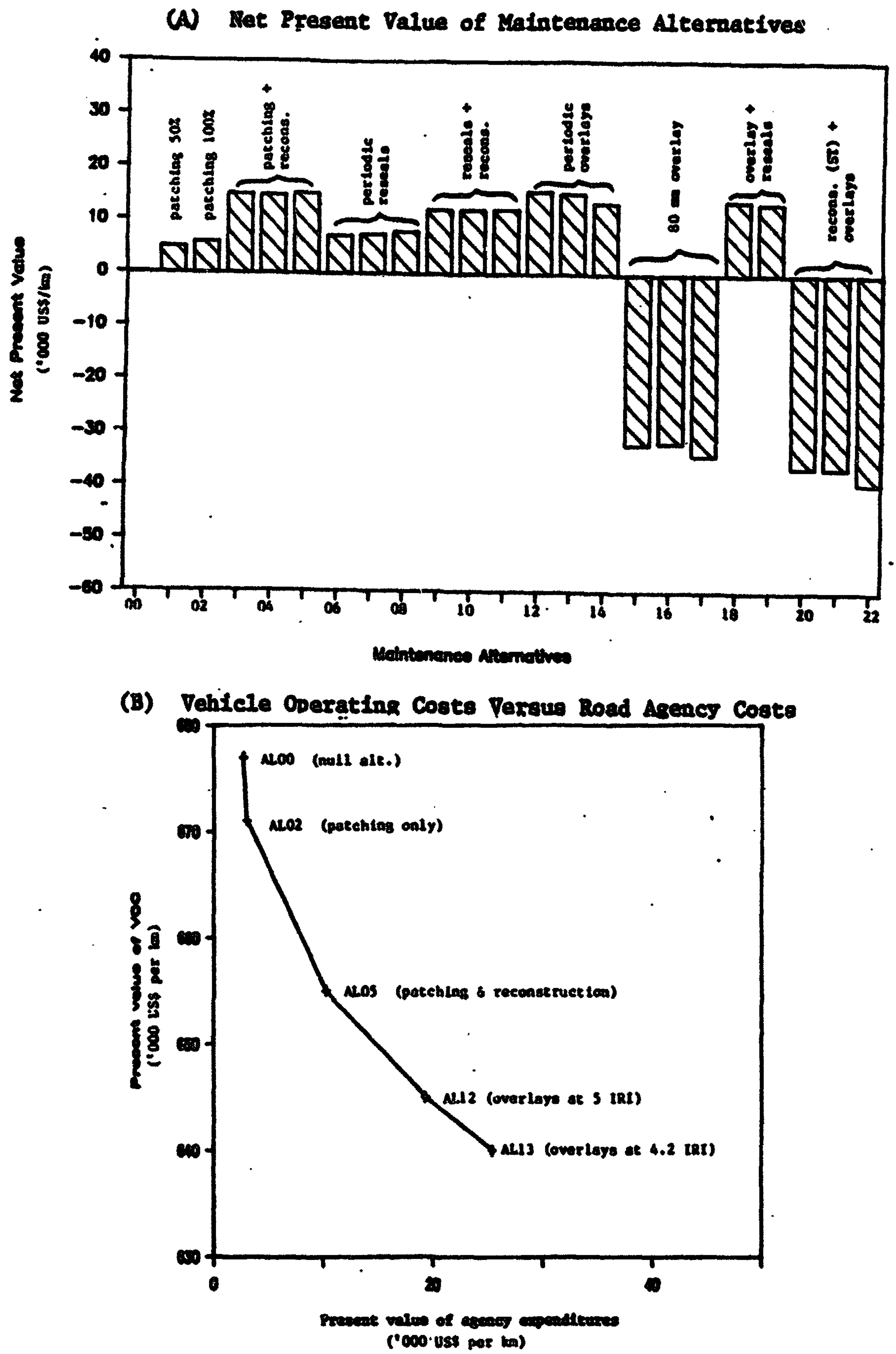
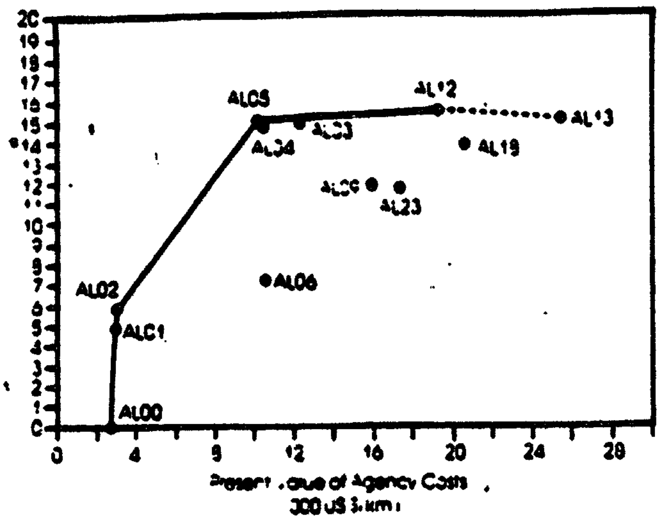
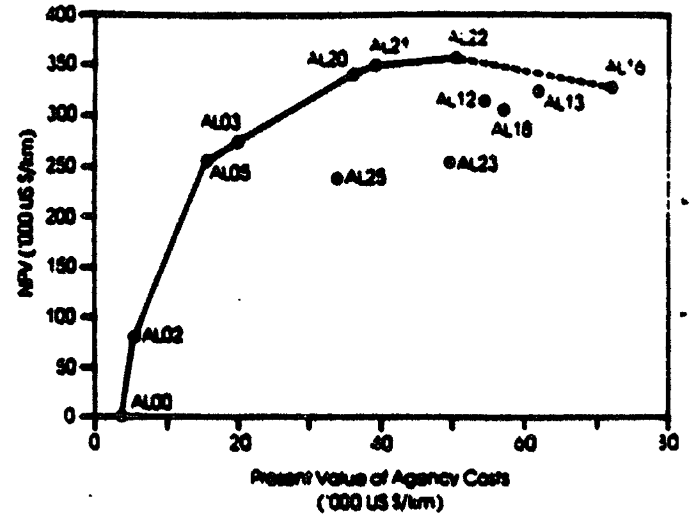


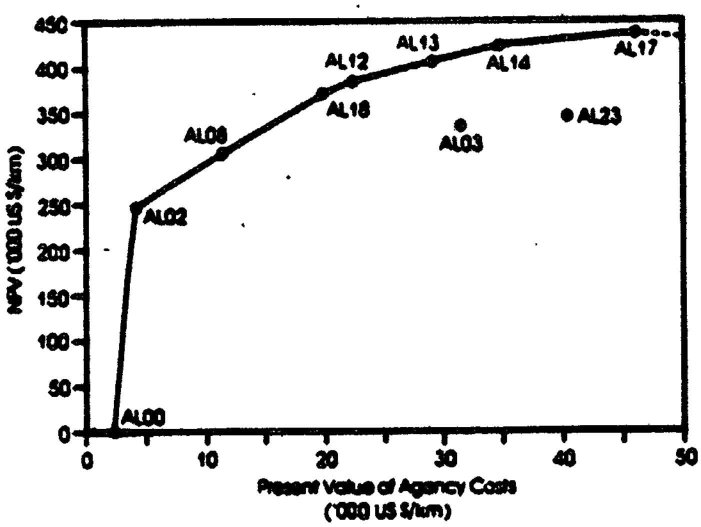
Figure A1: Low Volume Paved Road in Good-to-Fair Condition (Mali): Analysis of Maintenance Alternatives



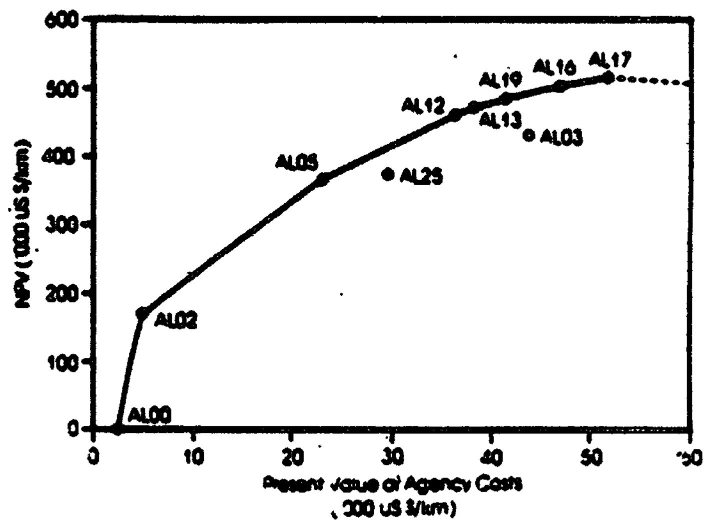
A. Low-volume (400 vehicles a day) paved in good/fair condition (Mali)



B. Medium-volume (700 vehicles a day) paved road in poor condition (CHILE)



C. Medium-volume (800 vehicles a day) paved road in fair condition (Costa Rica)



D. High-volume (1500 vehicles a day) paved road in poor condition (Costa Rica)

Figure A2: Net Present Value (NPV) Versus Agency Expenditures for Different Maintenance Strategies combination of maintenance options lying on the frontier. For example, in Figure A2-A (Mali), alternative AL09 has a net present value of $12,000 a kilometer at a present value of agency cost of $15,800 a kilometer. A higher net present value should be obtained at the same agency cost by using AL05 on part of the road group and AL12 on the rest, giving an average result that lies on the line connecting AL05 and AL12 on the graph. In the absence of budget constraint, the alternative that maximizes net present value should be selected. Agency expenditures beyond this point (AL05) result in benefits that are less than the increased costs, as reflected by declining net present value. The curve also shows the optimal order of retracting when agency resources are cut. The lower-order options are selected by successively reducing agency expenditures in ascending order of their marginal contribution to net present value. Where traffic is heavier and especially where roads are initially in poor condition (Figure A2-B and A2-D), the economic loss per dollar saved by the agency is considerably higher and, of course, successive reductions in expenditure have increasingly costly consequences. The steepest slope of the efficiency frontier, indicating the severest penalty, is reached when the only expenditure available for cutting (always excepting minimal routine maintenance) is pavement patching. In none of these choices is agency cost today traded off against significantly higher expenditures in the future; costs are simply transferred from the agency to the road users.

12. A summary of recommended maintenance options for paved roads, as generalized from the case studies, is presented in Box A3. These recommendations reflect interactions between traffic levels and road conditions, and the maintenance interventions needed to reduce the total road transport cost. In individual cases, the level and frequency of optimal maintenance actions may vary significantly from these recommendations because of variations in factor costs[3/], road construction maintenance practices, traffic loading characteristics, or environmental conditions.

13. On unpaved roads the primary maintenance-related determinant of roughness — and so of the cost of operating vehicles — is the frequency of surface blading. Simulation and costing of the effects of the various maintenance options (Table A2-B) show that blading costs and vehicle operating costs are closely balanced over a very wide range of blading frequencies. Optimal blading frequency is in the range of one blading every 4,000 to 8,000 vehicle passes which is consistent with generally accepted good practice (for example, one blading a month at 150-200 vehicles a day). Incremental increases in blading frequency within this range result in marginal reductions in user costs that are almost completely offset by corresponding increases in agency cost. Figure A3 shows plots of net present value versus blading frequency obtained from the Costa Rica case study. Even at low

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3/ For example, the results of the case studies suggest that surface treatments become a viable economic alternative to asphalt overlays when the cost of surface treatment drops to 25 percent of the overlay cost or less, on a unit kilometer basis.

Box A3

GENERALIZED MAINTENANCE OPTIONS TO MINIMIZE TOTAL ROAD TRANSPORT COST ON PAVED ROADS

Average Daily Traffic (ADT) (vehicles)	Initial Road Condition[a]/	Recommended Maintenance
<200	Good to Poor	Pothole patching only until roughness level becomes very high (8.5 IRI) and the traffic volume has risen sufficiently (ADT ≥ 200) to warrant pavement reconstruction.
200-500	Good to Fair	Pothole patching and overlays e.g. 40-mm asphalt concrete (AC) whenever roughness reaches 4.2-5 IRI. Surface treatments may be substituted for overlays under budget constraints.
	Poor	Immediate reconstruction of the pavement.[b]/
500-1000	Good	Pothole patching plus periodic overlays (40-mm AC at 3.5-4.2 IRI).
	Fair	Same as above but with an initially thicker overlay (80-mm AC) in cases of weak pavement.
	Poor	Immediate reconstruction of the pavement.[b]/
1000-2000	Good to Fair	Pothole patching plus periodic overlays (40-mm AC at 3.5 IRI). Where existing pavement is weak, the initial overlay should be thicker (80-mm). (Periodic surface dressings are economical on strong pavements in good condition).
	Poor	Immediate reconstruction of the pavement.[b]/
>2000	Good	Pothole patching plus periodic surface dressings (at 25% damaged area) in addition to periodic overlays (40-mm at 3.5 IRI).
	Fair	Pothole patching plus periodic overlays (40-mm at 3.5 IRI). Where existing pavement is weak, the initial overlay should be thicker (80-mm).
	Poor	Immediate reconstruction of pavement.[b]/

[a]/ Good = IRI less than 3.5
Fair = IRI 3.5-5.8
Poor = IRI greater than 5.8

[b]/ Some provision for patching and emergency maintenance should be made to keep the road serviceable during the reconstruction period.

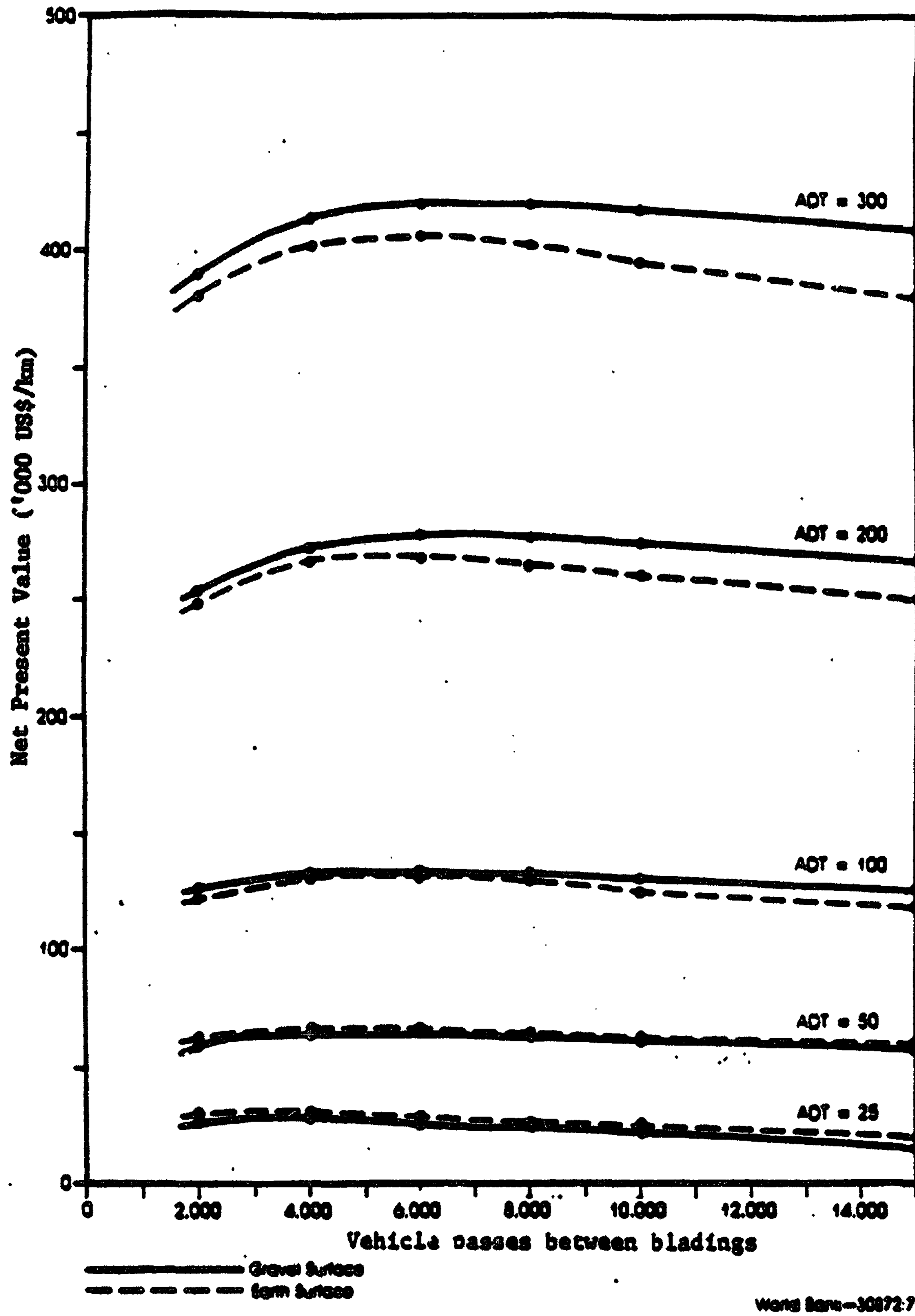

Figure A3: Variation of Net Present Value with Blading Frequency traffic levels (25 vehicles a day), the economic returns on blading are substantial. Blading once a year appears to be an acceptable minimum threshold. While blading once after every 4,000 to 8,000 vehicle passes would be an optimal policy, less frequent blading does not occasion serious economic loss, if the road is regraveled at appropriate intervals. Local conditions will strongly influence the maintenance options for unpaved roads. Extreme combinations of soils and climate (sands in arid climates, heavy clays in wet climates) may justify surfacing earth roads with gravel at an average daily traffic flow of fewer than 50 vehicles to ensure accessibility.

14. Where capital -- especially foreign exchange -- is scarce and unskilled labor is available at competitive rates (currently about $5 or less a day), the use of labor-based work methods for spot repairs on gravel roads and of simple drags attached to agricultural tractors or trucks to even out surface corrugations could prolong the time between bladings with mechanical graders. For unpaved roads with very low traffic volumes, increased use of labor for spot repairs could offer a viable alternative to mechanical means of maintenance, with the lower maintenance costs offsetting the somewhat higher vehicle operating costs.[8]

<u>Optimization of Maintenance Expenditures Under Budget Constraints</u>

16. When the maintenance budget for a network is less than that required for the overall optimum, allocations to specific road classes[4/] must be reduced from their optimal levels. However, maintenance expenditures should not be reduced uniformly across all road classes. The loss in net present value will be minimized by first reducing allocations to those road classes for which the efficiency frontier (para. 11) is least steep. In general, candidates for cutting are high unit cost maintenance operations on roads with low volumes and good existing surfaces. After the optimal activities have been completely replaced by next best options in a road class, the penalty for further cutbacks will be proportionately greater -- the frontier will be steeper -- and it may be economical to reduce allocations to some other road classes as well. Roads with very high volumes and poor surface conditions suffer the greatest loss in benefit for each dollar of reduction in maintenance outlay, and their allocations should be reduced last.

17. The effects of reductions in the maintenance budget on the choice of alternatives and on the resulting benefits were examined for the road networks of Costa Rica, Chile, and Mali. In Costa Rica the maximization of total net benefits would require spending an average of $12.5 million per year on maintenance over the first 10 years with $38 million needed in the first year alone to rehabilitate the paved roads in poor condition. Figure A4 shows the maximum net present value of benefits (discounted at 12 percent

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4/ Lengths of road sections grouped together on basis of similar design, traffic, and condition characteristics and, where appropriate, further stratified by regional, climatic or other relevant factors.

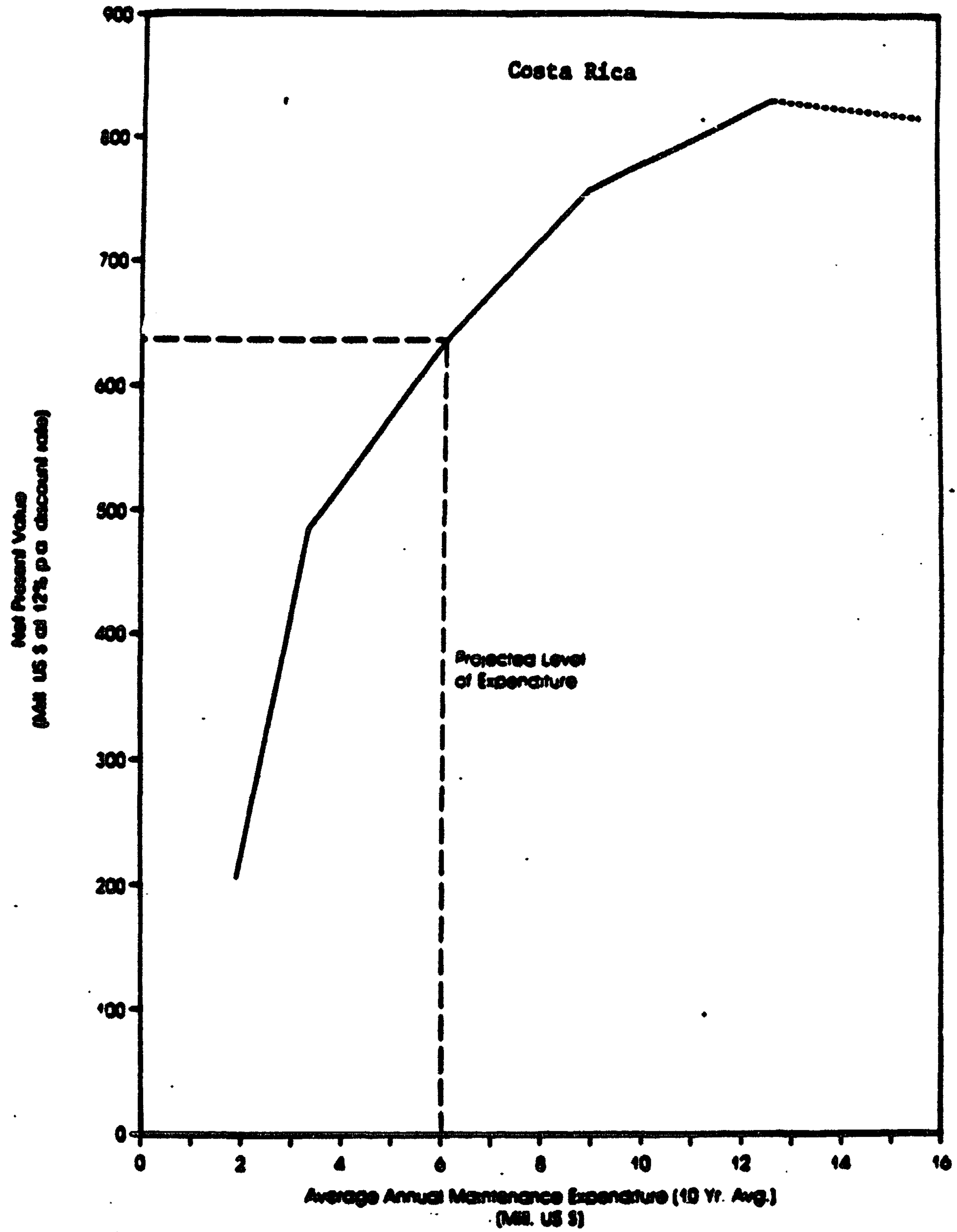

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Figure A4: Variation of Net Present Value for the Entire Road Network as a Function of Average Annual Maintenance Expenditures a year) for the Costa Rican road network under different levels of average annual maintenance expenditures, optimally allocated among different classes of road. If the budget is raised from the presently planned level of $6 million a year to the optimal level of $12.5 million a year over 25 years (or by $51 million in present value) the attainable net present value (with the best use of the funds in both cases) increases by $200 million, from $635 million to $835 million. The optimal program, even with unlimited funds, would not keep all roads in good condition. In Costa Rica, it provides for a high level of maintenance to keep two-thirds of the paved roads in good condition with the other third to be maintained to lower standards.

18. For Chile the best maintenance strategy for the road network is similar to that for Costa Rica: two-thirds of paved roads to be kept in good condition while maintaining the rest at lower standards. The optimal program involves immediate major expenditures on the rehabilitation of paved roads and assigns high priority to that activity even if the budget were cut back. That is the course Chile actually adopted, and the planned budget for maintenance of all roads — $140 million a year during 1984-91 — is approximately the amount required for the optimum derived in this study. If this budget were reduced for any reason, the losses would be large for this highly trafficked network.

19. In Mali, by contrast, where 84 percent of the paved roads carry less than 200 vehicles a day, only patching and basic routine maintenance is economically justified on most roads. The most economical option is indeed to keep only about 1 percent of the paved network in good condition with the rest of the network maintained at considerably reduced standards, mainly by patching and routine maintenance on paved roads and minimal blading on unpaved roads. Even so, about $9 million is required to clear Mali's backlog of economically warranted rehabilitation projects for higher volume paved roads currently in poor condition. And the average annual expenditure required to maintain the combined network of paved and unpaved roads is estimated to be about $6.2 million a year — about twice the current expenditure. If expenditures were raised to $6.2 million ($24.3 million in present value over 25 years), the present value of the benefits is estimated at more than $46 million.

20. Maintenance activities are often deferred during periods of austerity. For unpaved roads, as long as basic routine maintenance is carried out regularly, the primary effect of deferring blading and, to a lesser extent, regraveling is to increase vehicle operating costs during the deferral period. The effect on subsequent road restoration costs is not large unless the road is allowed to become virtually impassable, so that it has to be reconstructed, generally on a new alignment. For paved roads, on the other hand, both effects can be important: vehicle operating costs increase during the deferral period and the cost of later pavement rehabilitation can be increased substantially, depending on the stage in the deterioration process when deferral occurs. On newly constructed or rehabilitated pavements with light traffic loading, the effect of deferring maintenance (other than basic activities such as drainage) for one to five years is negligible. Once pavement condition becomes fair or poor, the impact is large.

Decision Criteria for Pavement Strength

21. When a new pavement is constructed or an existing one replaced or overlayed, the choice of design strength should take account of the reliability of future maintenance. Low probabilities of adequate maintenance and timely strengthening in the future favor building a strong pavement initially, since stronger pavements enjoy a longer grace period during which maintenance needs are minimal.5/ High probabilities of good maintenance will favor time-staging -- that is, economizing on today's pavement and strengthening subsequently as needs emerge.6/

22. To justify the time-staging of road construction a minimum probability of adequate future maintenance is required. To estimate this threshold probability, life-cycle costs for pavements with initial structural strengths, (SN), of 2.0, 3.5, and 5.0 were estimated for a range of traffic volumes and axle loadings in Costa Rica (light) and Mali (heavy). Three of the cases are illustrated in Figure A5. Each case shows life cycle costs (at a 12 percent discount) for the first 14 of the 31 maintenance alternatives for paved roads specified in Table A1. In case A, with average daily traffic (ADT) of only 500 vehicles per day and light axle loadings, it would suffice to use a normal design (SN=2.0) commensurate with the estimated ESALs since the life-cycle costs are consistently higher for a higher strength compensating design (SN=3.5), under all maintenance assumptions. But with heavier traffic a different conclusion emerges, as shown by Case C (ADT=2,500 and heavy axle loading). In this case, a normal full-strength pavement (SN=5) will have a lower life-cycle cost, under almost any assumption about future maintenance, than one with a lower initial strength (SN=3.5), which represents the time-staging option. At or above this combination of traffic and axle lodgings it would not pay to consider the time-staging option.

23. Between these two limits, the decision for or against time-staging of construction is reached by balancing the potential loss if no maintenance will be done against the cost saving from time-staging that would be realized if future maintenance (including strengthening) is performed as desired. In this way a threshold probability of performing good maintenance in the future is obtained, above which the time staging option could be justified. For Case B in Figure A5, for example, with an ADT of 1,000 vpd and light axle

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5/ A normal full strength pavement is defined as one designed on the basis of accepted pavement engineering principles to carry a specific number of cumulative Equivalent Standard Axle Loads (ESAL), until an unacceptable level of functional serviceability is reached. To compensate for inadequate maintenance, a higher pavement strength than given by normal designs may be warranted in certain situations.

6/ Time-staging at the network level is effective only when the condition of pavements is regularly monitored and evaluated with an appropriate pavement management system. Otherwise it is difficult to predict the critical points in the pavement life when a major maintenance intervention may be needed to prevent premature structural failure.

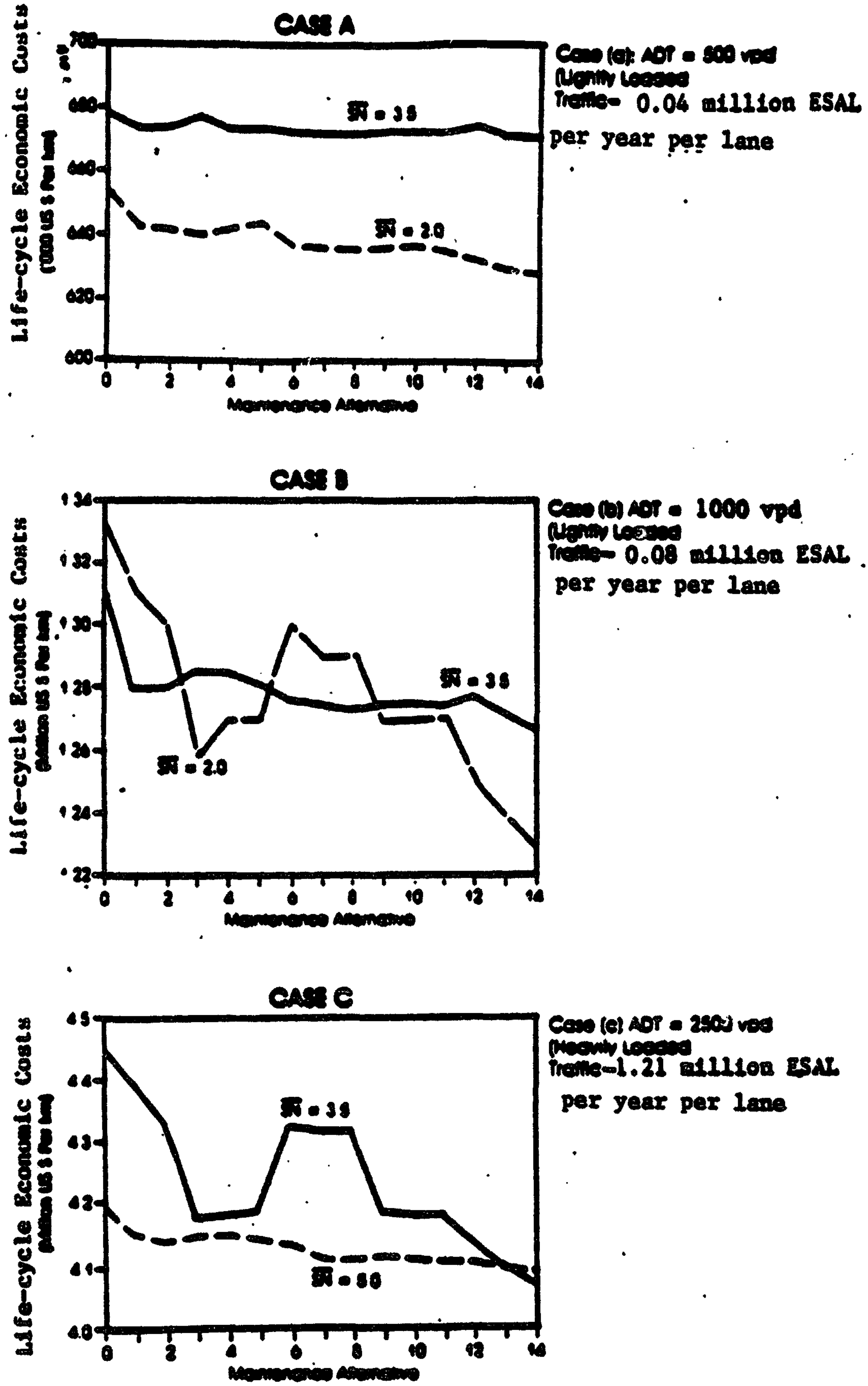

Figure A5: Influence of Maintenance Policies on Selection of Initial Pavement Strength (based on present value of life cycle costs, discounted at 12 percent a year) loads, this threshold probability is estimated at 33 percent.[7] In this case, time staging of pavement construction should only be considered if there is a one-third or better chance of good maintenance being performed in the future.

24. Under funding arrangements that favor construction over maintenance or where external aid agencies are willing to finance construction but not maintenance expenditures, it is often expedient to forgo maintenance until it becomes necessary to reconstruct the pavement. ALT3 in Case B codifies such a maintenance strategy, an option that would also reduce life-cycle costs significantly, if there is fair expectation that funds for reconstruction would be forthcoming when needed. In this case, a less than full-strength design could be considered for initial construction, if the probability of obtaining future funds for reconstruction is 45 percent or better.

25. Table A3 illustrates how the decision may vary in a wider array of cases. It maps out combinations of discount rate, daily traffic, and axle loading where the decision for or against time-staging is independent of the degree of uncertainty about future maintenance. In a middle area, however, the reliability of future maintenance matters. Time-staging is thus generally to be preferred if the probability of adequate maintenance in the future exceeds 30 or 75 percent, depending on traffic volumes and light axle loads. At higher discount rates (in this case 24 percent) time-staging tends to be a preferred choice even with high traffic volumes and axle loading and a relatively low probability of future maintenance. Where capital is cheap or a greater weight is attached to long-term benefits (an intergenerational issue), stronger initial pavements based on normal design generally dominate (say, at a discount rate of 6 percent).

<u>Economic Traffic Thresholds for Paving Gravel Roads</u>

26. Even with the best maintenance practice, vehicle operating costs on gravel roads are between 10 and 30 percent higher than on paved roads. In addition, the present value of the cost of routine maintenance and resurfacing is between five and eight times greater for a well-maintained, high-volume gravel road than for a newly built paved road. Paving is therefore

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7/ This may be derived as follows for Case B:

Let x = probability of optimal maintenance (ALT <u>14</u>)
1-x = probability of nil maintenance (ALT <u>00</u>)
Dopt = difference in life-cycle costs for initial pavement strength of SN 3.5 and SN 2.0; under ALT 14.
Dnil = difference in life-cycle costs for initial pavement design strength of SN 2.0 and SN 3.5, under ALT <u>00</u>.

Then, from the inequality:

$$(Dopt).x > (Dnil)(1-x)$$

or $(1.27-1.23)x>(1.33-1.31)(1-x)$

Therefore, $x>0.33$

Table A3 Criteria for Selecting Time-Staging Options for Pavement Design a/

ADT	Axle Loading c/	Minimum Maintenance Reliability for Time-Staging Option b/ @ Discount Rate of 6%	12%	24%
300	light	Compensatory design not applicable; low to medium strength pavements (SN < 3.5) based on normal design, adequate for this level of traffic volume and loading.		
	heavy	30%		
500	light	30%		
	heavy	n.a.d/	75%	
1000	light	95%	30%	
	heavy	n.a.d/	80%	
2000	light	95%	80%	15%
	heavy	Time-staging not applicable; high strength pavements (SN > 4.0) based on normal full-strength design appropriate.	90%	15%
2500	light		95%	50%
	heavy			60%

a/ The economic costs for paving (in thousand US$ per km, in 1984 prices, assuming all earthworks and structures already in place, were estimated as:

SN	Costa Rica	Mali
2.0	19.6	27.2
3.5	68.5	59.3
5.0	118.8	129.4

b/ Minimum probability of adequate maintenance in the future; time staging conditional to this minimum level of maintenance reliability, otherwise use normal strength design.

c/ Light axle loading is representative of conditions in Costa Rica (0.05-0.10 million ESAL p.a. per lane); heavy axle loading is representative of conditions in Mali (1.2 million ESAL p.a. per lane).

d/ n.a.=time staging option not applicable; use normal strength design.

indicated when the expected savings in vehicle operating and maintenance costs (relative to a well-maintained gravel road) exceed the present value of the paving cost.

27. These cost tradeoffs now seem to cover a wider range of traffic volumes than had commonly been assumed. Applications of the Bank's model in Costa Rica and Mali indicate that the breakeven traffic volume for paving may vary from under 100 vehicles a day to more than 400, depending on the costs of paving, the discount rate, the rate of growth of traffic, and the anticipated quality of future maintenance.

28. Paving thresholds are also sensitive to variations in assumptions about the quality of maintenance. Where experience shows that the probability of adequate future maintenance is low, the traffic threshold for paving is lowered. And if there are no budget constraints, an economic case can be made for an all-weather paved road that may remain almost free of major maintenance interventions for seven to ten years. In looking at total costs, however, more frequent regraveling and grading operations carried out efficiently are likely to prove more economical than paving, particularly if the future availability of maintenance funding is uncertain.

29. Paving gravel roads in arid zones is sometimes suggested as a means to alleviate the discomfort and inconvenience of travel on dusty roads, but it is difficult to quantity these benefits. Common observation suggests that vehicle speeds and passing opportunities on such roads are severely restricted by reduced visibility. The result is a traffic safety hazard similar to fog and congestion akin to that caused by heavily loaded slow-moving vehicles on narrow roads. Not enough empirical information is available on traffic flow and vehicle operating characteristics in a dusty environment to evaluate the benefits of paving roads in arid or desert areas.

30. Lower paving thresholds may also be indicated for roads located in river deltas (lower Bangladesh), old lake beds, sandy deserts, and low coastal areas due to the scarcity of gravel deposits and other sources of aggregate. In mountainous terrain, excessive maintenance costs resulting from erosion caused by rapid runoff, and frequent replacement of gravel, may warrant protecting the road surface with a bituminous surface. A possible technical alternative to using a gravel surface in these situations is to stabilize in-situ soils by small amounts of a suitable binder (bitumen, cement, lime, or fly ash) and then to protect the stabilized material from weathering and traffic, where necessary, by a light bituminous seal.

The Impact of Overloading

31. The onerous impact of overloading on pavement performance is reflected in the progression of roughness over time, given different maintenance policies and loading conditions on otherwise similar pavements (Figure A6). Case A is typical of Mali — 33 percent trucks with heavy axle loads, accumulating to about 14 million ESAL in 25 years. Case B is typical of Costa Rica — 25 percent trucks with relatively light axle loads,

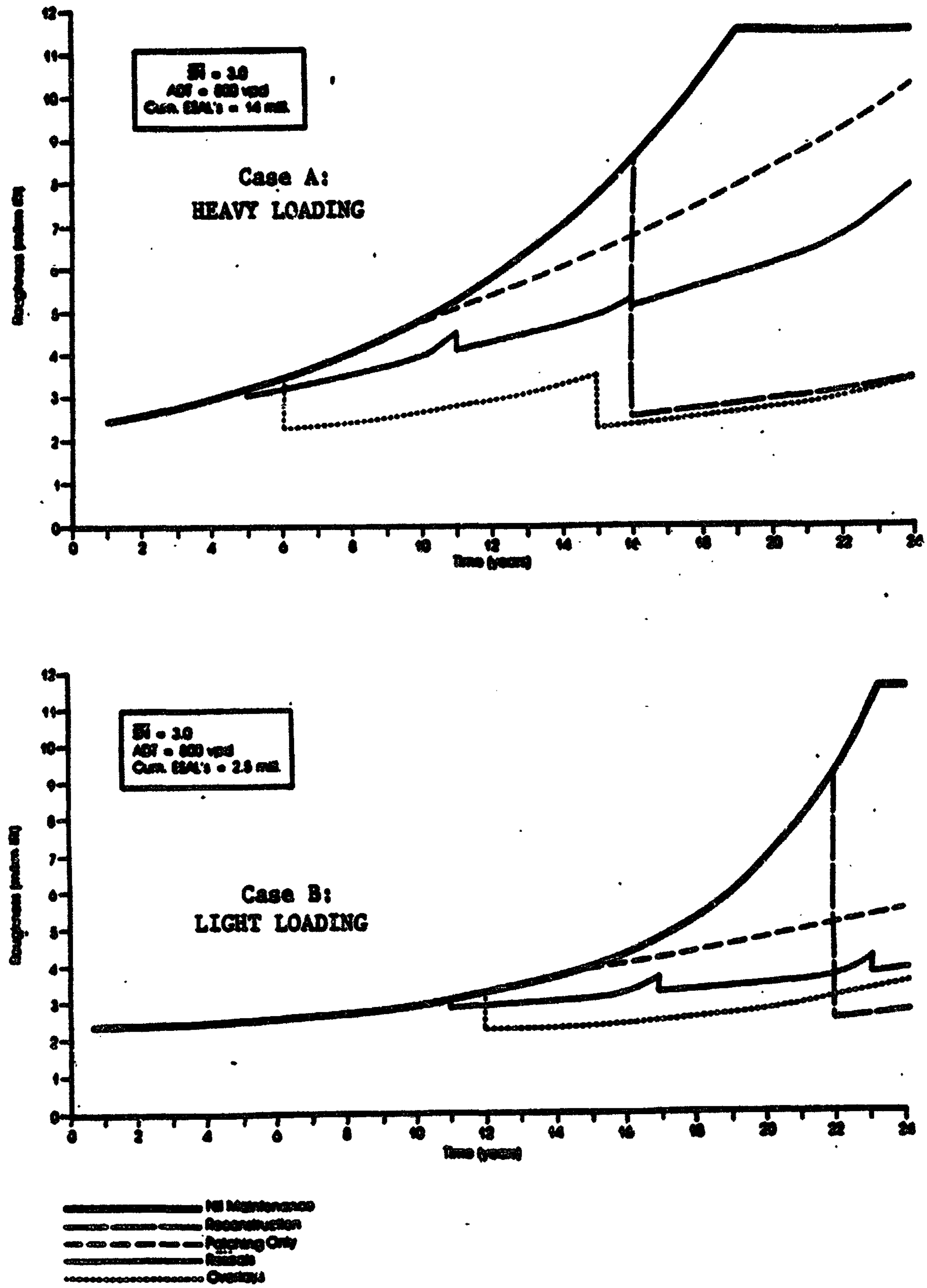

Figure A6: Effect of Traffic Loading on Pavement Performance accumulating to about 2.5 million ESAL per lane over 25 years.[8]/ Heavy loading significantly accelerates the rate of deterioration, and in this comparison the need for overlays in Case A is advanced by some six years. Even with optimal maintenance policies, the average life-cycle roughness remains higher with heavier axle loads. The results for Case A are typical of what has happened to pavements designed on the premise that axle load limits would be enforced, often an unrealistic assumption.

32. Although empirical evidence shows that a major part of pavement damage increases with the fourth power of the axle load, the regulation of axle loads has proved exceedingly difficult. Many road authorities have therefore built stronger and more expensive pavements based on actual pavement loadings than would be necessary with adequate control of axle loads. Expected changes in road transport technology resulting from road improvements (such as the introduction of combination vehicles in place of single unit trucks) should be taken into consideration in pavement design.

33. Research on the economic optimum for axle loads suggests that, limits in the longer term should be increased beyond the prevailing 8-10 ton single (and 13-16 ton tandem) axle loads; the economic gain from lower unit transport costs outweighs the loss in increased road damage. In the short term, however, the existing roads and bridges are not strong enough to carry heavier loads. So, a comprehensive plan for bridge and pavement strengthening should accompany an increase in axle load limits.

8/ The actual axle loads, on average, are about 60 percent heavier in Case A, partly due to the higher axle load limits (13-ton single axle) in Mali and partly due to overloading.

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