THE MAINTENANCE OF INFRASTRUCTURE AND ITS FINANCING AND COST RECOVERY

JULY, 1988

I. SIGNIFICANCE OF INFRASTRUCTURE MAINTENANCE

A. Significance to national economy

1. An efficient system of infrastructure is fundamental to the well-being of a nation and indispensable for promotion of productivity and growth of commerce, industry and agriculture. As infrastructure accumulates, quality of life is improved through increased health protection, convenience, facilitated communication and reduced cost of goods. Infrastructure facilities for water supply, sanitation, drainage, solid- waste management etc. are crucial for preventing communicable diseases and providing services for industrial and commercial operations. Likewise, the movement of labour, materials and products relies on a good transportation network to minimize delays, reduce transport costs and elevate productivity. Productivity is also increased by reducing vehicle trips through a well-maintained telecommunication network.

2. While infrastructure plays an important role in the economies of most countries, it also represents a considerable cost to them. On average, infrastructural investments in developing countries account for one quarter of annual capital formation and close to half the over-all capital stock. In quantitative terms, the Public Utilities Board providing only electricity, water and gas supplies to the city state of Singapore, for example, has assets totaling US$2.5 billion or the equivalent of US$1,000 per citizen. Including the entire spectrum of physical infrastructure, the per capita asset value could be as much as 5 to 7 times this figure, which, even for Singapore, approaches the equivalent of the country's GNP. The asset value of most developing countries exceeds their GNP and, invariably, the total foreign debt. Considerable proportions of the GNP may be invested in developing specific infrastructure sectors depending on government policies and priorities. Countries, such as Djibouti, Ethiopia, Lesotho, Malawi, Uganda and Zambia, which give priority to supplying their populations with water and sanitation facilities, for example, invest as much as the equivalent of 10 per cent of their GNPs in developing these sectors. At the city level, managing solid wastes can absorb as much as 40 per cent of an annual municipal budget. Given the sizeble capital most countries have already invested and continue to invest in creating infrastructure assets, it is clear that the manner in which these assets are maintained and the efficiency with which they are operated will have a considerable impact on the national economy and its prospects for growth.

3. The maintenance of urban infrastructure, in particular, has a remarkable influence on a country's economic productivity. Cities and towns absorb the largest proportion of infrastructural capital investments and make vital contributions to economic growth. Some 60 per cent of the gross national product of developing countries is generated in urban areas, although cities only accommodate a third of total national populations. In 1980, the 220 designated cities in China, for example, generated 75.4 per cent of the gross value of industrial output, 68.2 per cent of the state employment and 82.6 per cent of the nation's

profits and taxes, despite the fact that the aggregated population of the cities did not exceed 10 per cent of the national total 1/. Globally, the more urbanized a country is, the greater its economic productivity. Even agricultural modernization and productivity depend increasingly upon an efficient urbanizing process, to provide markets, processing facilities, goods and services. Inadequacies in urban infrastructure can increase considerably the cost of manufactured goods. For example, it is estimated that as much as 20 per cent of the initial capital investments by manufacturing plants in Nigeria are solely to compensate for unreliable and inadequate supply of power and water 2/. With so much of the nation's output depending on the efficiency of urban centres, well-maintained networks of infrastructure play a crucial role in eliminating bottlenecks to economic expansion and contribute to improving the country's potential to compete in international markets.

4. Infrastructural assets that are allowed to deteriorate represent an enormous drain on national wealth and cause serious undermining of the development process. The financial consequences of neglecting maintenance is often only seen in terms of reduced asset life and premature asset replacement expenses. However, more importantly, neglecting maintenance implies increased cost of operating facilities and wastage of related natural and financial resources. For example, reducing leakages in Bombay's water-distribution system from the original 18-36 per cent to 10-15 per cent, through appropriate maintenance measures, led to the saving of 250,000 cubic metres of water each day. The cost of developing a new supply to provide this quantity was estimated at US$170 million 3/. The true cost of the lost water would, in fact, be far greater than the taking account of lost sales revenue. Poor maintenance practices have been estimated to be responsible for the loss of as much as 50 per cent of all investments for water supply in developing countries period of less than three years. Likewise, the greatest benefits of highway maintenance actually accrue not to the highway authority but, rather, to road users, in the form of reduced vehicle-operating costs. As much as 15 per cent can be saved on wear and maintenance of vehicles and tires, when road surfaces are adequately maintained. This represents an annual saving of approximately US$5,000 per kilometre on a moderately traversed road 4/. For a country such as Ghana, with over-all paved surfaces exceeding 5,000 km. the annual savings could be as high as US$25 million: in addition, travel time could be reduced by between 10 and 25 per cent. Road accidents stemming from poor road maintenance account for 1 to 2 per cent of a country's GDP and involve replacing and repairing up to 15 per cent of the national vehicle fleet annually 3/. Given the proportion of foreign-exchange expenditure associated with the purchase and operation of vehicles, poor road maintenance can result in a steady depletion of foreign-exchange reserves. In countries such as Nigeria, where road accidents kill more people than common communicable diseases, the maintenance-related savings on medical expenses alone could prove significant.

5. Poor maintenance of infrastructural facilities can also present a drain on budgets at the local level. In Madras, for example, failure to maintain stormwater catchment tanks, which form an integral part of the city drainage system, demands the allocation of 10 per cent of the annual municipal budget for

undertaking inevitable flood-relief operations.

6. Most infrastructural facilities are composed of physical facilities, such as buildings, buried pipes, roads and electromechanical equipment. In general, poor maintenance of electromechanical equipment can increase service costs by a sixth. Where both electromechanical and physical works are deprived of maintenance, the over-all cost of service could increase two-fold 5/.

7. The postponement of regular maintenance work ultimately makes undue demands on national economies, to restore facilities. Savings from postponed maintenance are deceptive, since investments required to rehabilitate neglected facilities compound with time. Delays in conducting rehabilitation works eventually lead to the need for total replacement of assets. An example of the cumulative cost implications of neglecting maintenance is illustrated in the road sector, where it is currently estimated that US$90 billion is required in developing countries to arrest the deterioration of unmaintained roads and to clear up backlogs in rehabilitation work 6/. Delays in making such high investments could increase the eventual cost by two to three times the present estimate. In Accra, Ghana, alone, it is estimated that, at least, US$135 million - a *per capita* equivalent of US$135 - will be required to bring the road system up to adequate standards. Likewise, postponed maintenance currently demands that the North West Water Authority in the United Kingdom spend annually over US$102 million on rehabilitation and only US$42.5 million on maintenance 7/. While some rehabilitation expenses are inevitable, as a consequence of expired asset life- period, sustained programmed investment in maintenance will reduce investment in rehabilitation work and is usually a cost-efficient investment proposition. In the case of roads, the savings that regular maintenance bring through postponing of renewal works can be as much as two to three times the cost of regular maintenance work 4/. However, the most compelling argument favouring maintenance is the return that infrastructural maintenance brings. In the road sector, for example, the rate of return on maintenance-related investment was observed to reach as much as 100 per cent, in some cases, and average in excess of 40 per cent, while new construction only averaged returns of approximately 24 per cent 4/. In other words, the utility value of investment in maintenance is greater than that for new construction.

8. One of the most significant impacts that maintenance has on the national economy is the job opportunities that it generates. The magnitude of employment created will depend on the nature of the infrastructure and extent of labour-intensive maintenance techniques adopted. On average, however, physical infrastructural maintenance requires an annual labour input of 20 per cent of the total utilized in the initial construction. Where maintenance is poor, little advantage is taken of this potential. For example, the total staff employed per million consumers of water and sanitation services in Africa averages 224 as compared to Europe's average is 1,309 - nearly six times greater 8/.

B. Social Significance

9. Regular and adequate maintenance of infrastructure is fundamental for user acceptability and economically optimized utilization of national resources. When maintenance is poor, breakdowns can reach a point where users seek alternative means of obtaining the same service. In the case of rural water supply, for example, entire communities might abandon an unreliable facility to return to their traditional source of supply and, thereby, nullify the intended benefits of providing the facility. Such benefits include improved health protection and reduced time spent on collecting water - in Africa, women and children spend as much as 15 to 25 per cent of their time collecting water in areas lacking a formal service. The less reliable a service is, the more difficult it will be to obtain revenue for the service. Unreliable services can lead to community-relations problems and result in a complete breakdown of rapport between users and authorities. Maintaining reliability of service is alone a valid reason for maintenance of facilities.

10. Serious health hazards and extensive private property damage can result from poor maintenance of infrastructural facilities. Most users believe that available infrastructural services are of adequate quality to safeguard health: it is, therefore, an obligation of concerned authorities to ensure that this is the case. Implicit in this obligation is a duty, on the part of the authorities, to undertake mandatory maintenance. For example, failure to maintain water-supply facilities could threaten user-health through the contamination of supplies. Likewise, failure to undertake regular maintenance of stormwater drainage systems could lead to the clogging of channels and cause flooding and property damage. In countries such as the United States, of America, responsible authorities may be held liable for damages, unless evidence can be presented demonstrating that maintenance is conducted regularly 8/.

11. Popular support of governmental priority for maintenance must sometimes be generated, and it can be useful to stress the need for preservation of the national patrimony, the contribution of well-maintained infrastructure to the development process, and the generation of national pride in possessing adequate infrastructural facilities. Such an approach was adopted in Niger to increase highway maintenance budgets from about 4.5 per cent of the central government revenues in 1965 to 7 per cent from 1970 onwards.

C. Technical Significance

12. Many technical reasons indicate the value of maintenance. Infrastructure is often perceived as beginning and ending with the planning and execution of projects for physical facilities. Consequently, maintenance is given little emphasis, causing facilities to operate below their intended capacity and, thereby, not making cost-effective use of them. For example, traffic congestion in most cities results more from poor utilization of road space and inadequate maintenance than from capacity deficiency. Where pumps are not regularly calibrated, their efficiency might be reduced to a third of their potential. The savings from making good use of existing facilities can be

considerable; the Government of Cote D'Ivoire found it possible to eliminate or defer several expensive infrastructural projects and reduce planned investments between 1981 and 1984 by US$120 million by improving the utilization of available infrastructural facilities 9/.

13. Knowledge of maintenance needs is important for promoting infrastructural operational efficiency and can serve as an input to management decision-making. Accurate figures on infrastructure-production, service-consumption and maintenance-demand patterns are essential in planning new investments. Where maintenance is given little attention, this information might not be available, and decisions about the capacity of new works, types of equipment and facilities, and timing of new investments will be based on conjecture, inevitably resulting in sub-optimal utilization of investment resources. Maintenance records provide useful feedback for both management and technical-design decision-making.

14. There are many instances where maintenance might represent the sole option in meeting demands for infrastructural services. In Mexico City, where water use already exceeds renewable supplies by over 30 per cent, maintenance measures, such as leak detection and control and use of water- conserving practices, might represent the only option, in the short term, for balancing supply and demand. Maintenance of existing facilities, as a means of increasing infrastructural capacities to serve increasing numbers of users, will have to receive first-priority attention in certain countries as capital investments in new works escalate beyond the resource-capacity of governments. For example, in developing countries, the increase in unit cost of urban water supply, through even a minimal service level such as standpipes, was observed to have increased by 50 per cent between the years 1980 to 1985 10/. As infrastructure coverage increases with time, investments will, by necessity, shift from capital works to maintenance. For example, since the number of people served with water supplies in the Americas has steadily increased and currently accounts for 84 per cent of the total urban population, recent years have seen a shift in investment priorities from capital works to maintenance.

15. Most infrastructural elements interact with others in such a way that failure to maintain one can adversely affect the operation of another. For example, failure to provide a reliable solid-waste management service could result in the deposition of refuse in stormwater systems which could lead to their clogging. Likewise, failure to maintain the telecommunication system will result in increasing the number of vehicle trips, which could increase traffic and lead to road congestion. The maintenance of infrastructural facilities can, therefore, often be justified as a means of maximizing the capacity not only of the concerned infrastructural facility but also of others that interact with it.

16. Where little or no maintenance is undertaken or where maintenance is conducted on an ad hoc basis, the funds devoted to maintenance efforts might not be utilized optimally. Only where sustained programmes of planned maintenance are in place would information be gathered to ensure cost-effective investments in maintenance. For example, timeliness of maintenance interventions is critical for preserving assets and maintenance-

related investments: there is little point in clearing stormwater channels and gullies after the commencement of the rainy season, since activities should be undertaken immediately preceding rains. Likewise, gravel-road grading is most cost-effectively undertaken immediately after rains, when upper layers are still moist. An example of the costsavings possible through timely maintenance was seen in a West African country where deterioration during the one-year delay in starting reconstruction work on a road eventually required an investment a third higher than initially planned for rehabilitation work.

D. Maintenance Versus New Construction

17. Very few developing countries have devoted adequate resources to maintaining infrastructural facilities over the past two decades. Consequently, infrastructural conditions in many countries are extremely poor. Where infrastructure investments have been made, they have been devoted mainly to the construction of prestigious new construction projects, even though maintenance often presents a low-cost alternative. A blance between maintenance and new construction is often necessary to optimize resource utilization, and a variety of reasons, besides those already considered, supports the assigning of high priority to maintenance. Funds for developing and maintaining infrastructure are often minimal, and there are important competing priorities. Unlike many other demands on the public budget, maintenance can often be postponed at no immediate visible cost, and the funds can be saved for what seem to be more pressing needs. However, without serious attention to maintenance, a generation of infrastructural investments is at risk. Investment in infrastructure is so large that preservation of the assets and operation at full design capacity justify careful maintenance.

18. For example, since 1965, over US$20 billion have been spent on new sanitary sewer construction in the United States of America. Premature failure or under-capacity utilization of these facilities, caused through diverting essential maintenance funds to construction of new assets, cannot be justified, in view of the colossal investments already tiedup in existing assets. This is especially true when considered from the point of view of the actual expenditures demanded by maintenance. Maintenance expenditures are very small: routine maintenance of physical infrastructure, such as water supply, sewerage, road and drainage systems, requires an annual expenditure of no more than 1.5 per cent to 4 per cent 4/, 11/, 12/ of the replacement cost of the facility. Only in the case of solid-waste management services, where vehicles and equipment account for 70 to 80 per cent of the total capital and require frequent replacement, does the proportion of maintenance expenses reach the range of 10 to 15 per cent of asset-replacement cost. The benefits and returns on investment in maintenance can also be considerable. On average, an estimated annual total of only 1.7 per cent of total replacement value of US$1.5 billion is required for maintenance of Bolivia's gravel-road stock. The corresponding benefits were five to ten times this investment, with savings resulting from postponement of renewal and reinvestment. The relatively small investments demanded by maintenance, the exponential increase in maintenance costs when rehabilitation is required and the need to conserve the large investments made in infrastructure justify the consideration of routine maintenance as a fundamental resource-

conserving strategy rather than an alternative to new construction.

19. Many developing countries have little alternative to concentrating their meagre resources on maintaining existing assets. The current economic environment for developing countries is characterized by sluggish growth, high inflation, high and volatile interest rates and persistent internal and external budget deficits. One result has been declining investment in infrastructure. This phenomenon is by no means limited to developing countries and is becoming increasingly visible in developed countries 13/, as a result of budgetary restrictions. Whatever the reason for reduced or exhausted lines of credit, the sustaining of productive infrastructure might present the only affordable infrastructural investment strategy in these countries, even if only for the short term. Virtually all African nations had exhausted their lines of credit by the early 1980s, and these countries will have little option but to adopt maintenance as their principal investment priority.

20. Underlying the present shortage of funds for concurrent capital and maintenance investments is the poor revenue generated from infrastructural investment. One of the important reasons for this is the poor services communities receive as a consequence of long-neglected essential maintenance work. It is axiomatic that, where the level of service is consistently poor, willingness to pay service charges will be low, with a consequential impact on the revenue-generating potential of the infrastructural asset. Maintaining infrastructural facilities as a means of sustaining satisfaction of consumers is indispensable, in order that the revenue-generating potential of facilities be maximized.

II. PROBLEMS OF CURRENT SYSTEMS

A. Institutional Problems

21. The distribution of responsibility for infrastructural maintenance varies from one sector to another and from one country to another. While over-all responsibility for maintenance invariably lies with one or more governmental agencies, execution is generally effected through a combination of public-sector and private-sector actions. Unfortunately, the distribution of responsibility within governmental agencies for most infrastructural maintenance is rarely clear-cut. The multiplicity of ineffective agencies, with gaps in jurisdictions and mandates, the competing interests involved and the limited framework for encouraging and supporting actions at local levels present serious constraints in many countries. In extreme cases, organizational structures do not include sector-specific maintenance units, and maintenance functions, therefore, come under a general public works maintenance unit. Such general maintenance units are incapable of attending to the specific maintenance demands of several infrastructural sectors.

22. Gaps in jurisdiction occur in two ways. First, institutional jurisdiction may be so defined as to exclude sections of infrastructural networks from attention. For example, in Accra, Ghana, the cleaning and structural maintenance of all drains alongside roads, on the one hand, and of main drains, on the other, are clearly delegated to two independent institutions. However, it is unclear who is responsible for the maintenance of the interconnect drains 14/. Secondly, definition of jurisdiction and allocation of resources between central and local institutions may be such as to favour one at the expense of the other. Many countries, for example, have strong institutions the maintain their highway networks and, at the same time, delegate responsibility for urban road maintenance to independent weak local institutions which are incapable of coping with the exacting traffic demands in urban centres. Such imbalances fail to take account of the importance of urban centres to the national economy. The legal responsibility for planning, financing, executing and monitoring maintenance work, among different levels of government and within the central government, is often subject to serious ambiguities. The most serious of these is the scope, in present legal contexts to permit action at local levels and to foster community involvement in the process.

23. While many countries acknowledge the advantages of decentralization and are actively pursuing it, with the objective of reducing regional disparities and lessening administrative bottlenecks, infrastructural maintenance operations generally continue to be centrally controlled. There are few formal channels through which needs at local levels can be voiced at central government levels, and this perpetuates inappropriate allocations of resources for maintenance at local levels.

24. Problems in maintenance have also risen as a consequence of local municipal authorities inheriting, for operational and maintenance purposes, infrastructural facilities which have essentially been planned, designed and, often, constructed by a central authority. The lack of local involvement in the planning and design processes and poor vertical communication between local and central agencies have led to maintenance problems which

could have been adequately addressed at the design stage. Realizing the shortcoming of such a centrally controlled approach, the water and sewerage authority for the state of Uttar Pradesh in India, for example, undertook reforms to involve local water-supply and sewerage authorities at all stages of project development.

25. The problem of institutional deficiencies is greatest in rural areas and is particularly marked in the water-supply and sanitation sectors. In contrast to urban water supply and sewage disposal, small towns and rural areas are unable to support financially institutions capable of providing adequate services. In the past, failure of over half the installations within a few years of project completion has been common. This is often a result of central agencies attempting to install facilities without adequate trained local staff and resources for long-term maintenance. While the promotion of local community participation has emerged as a means of overcoming this problem and establishing sustainable local maintenance, few institutions have the necessary legal and technical capacities to permit and encourage such participation.

26. Worse than the vertical integration of maintenance departments, from central to local levels, is the horizontal integration of sectoral agencies and departments at each level of government. Most infrastructural facilities interact with one another in such a manner that, if one is poorly maintained, the operation others will be affected. In addition, some maintenance works for different infrastructural facilities entail common work schedules, such as the digging of utility trenches, and, unless these are co-ordinated between the agencies, a considerable wastage of resources will result. The East Wind Road, one of the busiest roads in the City of Gangshore, China, was, for example, dug up three times by independent agencies within the space of five months, each to attend to its own utility need 15/. Despite the obvious need for interagency and interdepartmental co-ordination, such collaboration is extremely poor in most countries.

27. The problem of co-ordination becomes especially confounded, when such collaboration requires diagonal integration, i.e., across different levels of government and across different sectors. The principal responsibilities of many municipalities in the transport sector, for example, are the maintenance of all roads except national roads and the construction of secondary and local roads. Frequently, however, responsibility for safety and enforcement comes under the Ministry of Transport and the national police. Where poor co-operation exists between the municipality and national agencies, maintenance efforts are seriously hampered.

28. Within the structure of sectoral institutions, maintenance units continue to be accorded low priority and status. The assigning of undue emphasis to construction, by many governments, is in part responsible for this and it is not uncommon to see maintenance staff being redeployed for construction activities. The size of maintenance units is rarely commensurate with the responsibility they are expected to shoulder and allocation of internal responsibilities within units is too vague to be effective.

29. The size and structure of maintenance departments depend intrinsically on the proportion of work conducted in-house and that contracted to private entities. Depending on the type of infrastructural facility, different types of maintenance operations are usually contracted out. However, most maintenance departments are entrusted with the responsibility of undertaking preventive, corrective and routine maintenance in-house and contract out all periodic and rehabilitative maintenance. In practice, little if any, preventive maintenance is undertaken and most governmental efforts are devoted to taking corrective action in response to political and public requests. For example, even though most water-supply agencies are aware that approximately 30-50 per cent of the water they produce is unaccounted for, i.e., lost through leakages in the distribution system and illegal connections, few have introduced routine programmes to detect these losses. Only when such losses surface and become visible are they attended to, following public complaints.

30. The choice of a particular organizational structure in some cases is historical and totally out of context with present needs: consequently, they are ineffective in addressing maintenance problems. Organizational structures for refuse disposal in developing countries, which continue to be based on those adopted under colonial systems, provide a case in point. The responsibility for refuse disposal under these systems is usually entrusted to the medical officer of health and the public health inspectors or sanitary officers who manage solid-waste disposal amongst other duties, such as control of epidemics and insects, inspection of slaughterhouses, and food, public health education, management of immunization programes and sewage and nightsoil disposal. Hence, it is not surprising that little attention is devoted to solid-waste disposal. Such a structure is completely inadequate when applied to newly emerging large urban areas, and lack of specialized knowledge prevents such an organizational structure from being effective in undertaking requisite maintenance work.

31. Routine maintenance is undertaken only for specific infrastructural facilities, such as roads, and only when the respective departments are endowed with adequate human and financial resources. Although the size of maintenance units should in fact be established through the optimized division of maintenance work between private and public agencies, this is rarely the case, and consideration of social and political objectives, such as the creation of employment, has caused distortions in maintenance expenditures, reduced productivity and caused delays in maintenance work. For example, of the K.Shs.210 million allocated to the district roads departments in Kenya from the central budget, 90 per cent was used for purposes of personnel-related expenses leaving little for operating expenses, (such as fuel, spare parts and bitumen) 6/.

B. Maintenance management problems

32. One of the fundamental problems with the maintenance of infrastructural facilities is that most governments do not have a clear policy or plan with regard to infrastructural sector as a whole. Where such policies and plans exist, they have failed to receive the priority they deserve. This stems primarily from inadequacies in management practices in sectoral agencies. Insufficient record-keeping and data-gathering and poor

monitoring have led to failure to understand the importance of maintenance. Decision-makers have been kept ignorant of the basic issues, managers have been unable to present the right facts, and engineers and technicians have been given little guidance in designing, implementing and maintaining new facilites. Fundamental maintenance issues have, therefore, been omitted from the policy-making and planning processes, and budgetary allocations have, hence, rarely reflected need. Meagre resources for maintenance have, been poorly utilized, and lack of feedback to designers has prevented them making corrections and improvements in design.

33. The lack of appreciation of maintenance issues resulting from deficient management practices, has given rise to misplaced investment policies within sectors. Many water authorities in Central America, for example, have pursued a policy of expanding their services based on new capital investments to obtain water from far afield, when increased quantities could well have been most economically obtained through well-designed leak-control programmes. Generally, many advances have been made in methods of testing and determining life of assets and predicting maintenance requirements; however, these remain unknown to many managers.

34. Among the matters to be considered under maintenance-department resource management are fixed assets, equipment, land, staff and financial resources. With regard to fixed assets, few, if any, intensive field inspections and tests are carried out to determine maintenance priorities. The need for inspection and tests can only be waived when an adequate monitoring system of data collection and record keeping is in place; this, however, is rarely the case. Even where attempts were made to introduce such monitoring controls, these invariably proved beyond the capacity of local staff. Daily work orders are often issued; however, they are rarely processed to analyse trends of complemented by job- completion reports containing maintenance diagnosis. Without information on maintenance priorities, most maintenance departments are unable to define even a basic programme of preventive and routine maintenance. A majority consequently only respond to requests for corrective maintenance, originating external to the agency: a "management by crisis" method predominates. Even so, delays are incurred in attending to the work which then sometimes demands greater resources to restore than if the requests were attended to promptly. One of the reasons for the delay is that materials required for the restoration work might not be readily available. This usually follows from poor management procedures used to stock and control material stores. Unnecessarily lengthy bureaucratic procedures to obtain the release of material and equipment are also responsible for causing delays.

35. The responsibility for the operation, service and repair of equipment used for maintaining infrastructural facilities is rarely delegated to specific individuals, and a sense of responsibility for proper equipment use is often lacking. Records of release, service and maintenance of equipment are usually not kept in any order that could enable managers make comparisons between equipment, determine demand for spare parts and establish availability, use and productivity. In the absence of such records, managers have little basis upon which to determine the extent to which such equipment should be retained

in the department or hired. In a road maintenance survey conducted by the World Bank in 1985, it was noted that vehicles and equipment were notably underutilized in West Africa and Latin America. Observed annual equipment and vehicle utilization rates were 420 and 840 hours for West Africa and 750 and 800 hours for Latin America respectively. All such annual utilization rates fall short of the 1,250 hours of operation generally regarded as efficient for equipment and vehicles 6/. Under such conditions, a decision to hire equipment and vehicles would have proved most economical. Essential economic costing is rarely undertaken to guide management decisions regarding the balanced use of equipment and labour-intensive techniques.

36. Perhaps the area where management is most wanting, in many countries, is in the area of personnel management. Supervision is usually minimal; field inspections too sparse and their timing predictable; little if any critical appraisals are made of the work done, to guide staff as to the standards to be attained; and job assignment is too vague to inculcate a sense of duty and accountability. Daily-activity reporting is not adequately maintained, and communication between field and central offices is inexpeditious. Where management is particularly poor, it is not uncommon to see personnel trained for a specific maintenance function deployed for duties unrelated to their training. Weak performance is often blamed on inadequate training, when, in fact, it is usually a result of inadequate, non-existent or unenforced personnel-management policies. Central and local treasuries often liberate the entire fund allocation for a specific year's operations at the start of the fiscal year. In the absence of definite programmes of maintenance with corresponding work schedules, managers often find it a problem to recruit staff commensurate with available funds and frequently have to lay off personnel towards the end of each fiscal year. This does little to engender esprit de corps among employees. In other cases where large labour forces are maintained, operations become suspended towards the end of each fiscal year, as there are no funds for materials, fuel etc.

37. A common feature in most maintenance departments is the absence of accountability, resulting from poor management of maintenance funds. Seldom is the allocation of funds linked to explicit plans, and hardly any ex-post evaluation of completed works is undertaken. Financial flows through the organization are not adequately controlled for costs nor related to specific performance indicators. Administrative practices for contract management are subject to few checks, and contract monitoring and supervision are inadequate to control output quality.

C. Design/construction-generated and user-generated problems

38. All infrastructural facilities, however sophisticated, require a minimal level of maintenance in order to continue operating at their design capacity. The extent of this minimal maintenance will be largely governed by the standards adopted in design, the ability to manage and supervise construction to ensure conformity to these standards and the use/abuse of the infrastructural facility. In general, where infrastructural facilities are designed and constructed to high standards and are used as designed, the maintenance requirements will be minimized. In practice, however, economic considerations establish limits for standards. Ideally, such standards should be determined in a

manner that will optimize the over-all construction and maintenance cost of the facility: this, however, is not done in practice. Various assumptions made at the design stage, when not conformed with in practice, during construction and subsequent use of the facility, create many related maintenance problems.

39. In designing a stretch of road, for example, it is not unusual to assume that the stormwater gullies provided along it would be degritted periodically and in a timely fashion (e.g., before the rainy season). However, where such maintenance is not undertaken, the efficient removal of stormwater from the surface of the road will be impaired, which in turn will lead to rapid road-surface deterioration and increased road-maintenance problems. Many government departments entrusted with the design of infrastructural facilities consistently increase standards beyond those which are technically necessary, in order to compensate for possible failures that emanate from poor maintenance. Clearly, such overdesign often implies drastic increases in capital investments which can only be effectively controlled through improved performance in maintenance.

40. Requirements for maintenance and renovation of infrastructural facilities can be substantially reduced when construction is closely supervised. The technology for sewer-pipe jointing using various materials, for example, is well established, and, at the design stage, it is common to specify the manner in which this must be undertaken during construction. Even so, owing to inadequate supervision at the construction stage, poor pipe-jointing accounts for the principal cause of sewer blockages in most countries.

41. All infrastructural facilities are designed to specific technical criteria and presuppose a mode of usage which conforms to these criteria. Poor enforcement and lack of user involvement during project development sometimes cause infrastructural facilities to be abused. For example, axle loads of goods vehicles, in most developing countries, frequently exceed permissible limits (which form the basic criteria for design), and where little or no control is exercised to reduce such overloading, rapid disintegration of the road surface results. In some cases, where vehicles were originally fitted with multiple rear axles, wheels are removed from the second parallel axle, thereby increasing the load on the remaining axles. Even where overloading is so blatant, few countries possess enforcement measures to arrest such abuse. Similarly, the introduction of sewerage systems, especially in low-income areas, without corresponding community education and information on the limitations of the system, has resulted in the discharge of material not designed to be transported by the system, which, in turn, has demanded a level of maintenance higher than is usual for such systems.

D. Staffing and training

42. In relation to the amount of maintenance work that requires attention, a majority of maintenance departments experience chronic shortages in staff; however, in relation to the budget available for maintenance work, staff surpluses are common. Gross imbalances occur in staffing, with a tendency towards over-staffing at the low echelons of unskilled and semi-skilled

personnel, and, at the same time, serious gaps and shortages in staffing at the supervisory, managerial and professional levels. Governments have encountered particular problems in attracting and retaining requisite skilled staff: limited professional interest in maintenance, poor salaries and low public esteem have been primarily responsible for failure to retain managers, engineers, technicians, foremen, mechanics and others with special skills. Possibilities of introducing incentives to reverse the trend have proved difficult, owing to inflexible civil-service salary structures. In Ghana, for example, the monthly wage of an artisan at the department responsible for infrastructure maintenance could easily be equal to the daily remuneration of an artisan operating informally on the general construction market. The lack of qualified personnel at middle and upper management is, in fact, a crippling constraint that pervades all maintenance operations and is a principal cause of the poor performance in maintenance departments. High staff turnovers at these levels impede work continuity.

43. While overstaffing of unskilled personnel might, in part, result from inadequate middle and top management, it is, however, frequently a result of political or social policies targeted on employment objectives. Imbalances in general and managerial staff have given rise to poor personnel control and guidance, widespread absenteeism and very low productivity. In Poland, for example, understaffing of maintenance units is considered to be the principal cause of unsatisfactory maitnenance of infrastructure facilities: in 1983, there was a short fall of 35 per cent of the staff required to fulfill basic maintenance tasks. Again, owing to staff shortages, the usual standard of employing one artisan per 2-10 kilometers of water lines, for operation, conservation and routine repairs, has not been achieved and, instead, tools and equipment have been introduced to substitute skilled labour regardless of the cost disadvantage. Similarly, the national standard of maintenance of 6-9 km of sewer per artisan has been reduced to 14 km per artisan.

44. The first step in undertaking maintenance work is to know what to do and how it should be done but knowledge of maintenance-need identification and execution is often weak. While many maintenance works are in no way dissimilar to construction works, specific tasks, such as the use of television cameras to assess sewer deterioration, require specialized training. The operation of most equipment required for maintenance and the service and repair thereof necessitate skilled personnel. Training programmes designed to meet maintenance-need assessment and skill development have, far too often, lacked focus and have rarely been related to organizational priorities. Various developing countries have no educational establishments that provide training in the infrastructure-sector-specific subjects, and few opportunities exist to see and evaluate modern systems. This, for example, is the case for the urban-transport sector in West Africa: there is, therefore, a basic lack of understanding at all professional levels of the concept of transport planning and of contemporary maintenance methods. Where training establishments exist, maintenance is given little prominence, and few establishments undertake any kind of research related to maintenance.

45. Efforts to train isolated individuals have been unfruitful, as these individuals rarely return to continue their functions for extended periods. Programmes have, sometimes, been envisaged only for mechanics and operators, for example, although field supervisors and inspectors were equally in need of training. Training programmes geared to training entire institutions have yielded the best results in raising over-all organization competence: the nature of maintenance operations is such that in-service "action-training", in which participants are enabled to undertake particular tasks in their normal course of duty under training staff supervision and monitoring, have proved most effective. Training programmes have frequently been designed with too rigid a framework to permit changes in response to need over a period of time. They have, in many cases, been seen as a "one-off" effort: consequently, training has not been adequately institutionalized as a continuous function, despite the fact that large staff turn-overs demand this. Areas of training in maintenance that have, in particular, received sparse attention are the maintenance-need assessment and quality-control procedures and practices.

E. Finance

46. A perennial problem in maintenance is to ensure that sufficient funds are effectively spent on a continuous basis in undertaking routine preventive maintenance operations. The fiscal base of departments entrusted with this responsibility, at central and, in particular, local levels, remains extremely weak. Funds available to these departments are often so insufficient that they are unable even to respond to crisis maintenance needs, let alone undertake preventive maintenance. Accompanying the lack of funding is the inability of local and central governments and related sectoral agencies to mobilize sufficient funds specifically for maintenance purposes in addition to capital-repayment obligations. There are a number of reasons for this financial gap. Non-fiscal reasons, such as lack of awareness of the importance of maintenance amongst policy-makers, undue funding bias towards capital development, lack of clear sectoral policies and plans and political objectives of impressing public opinion with new works, are only in part responsible for funding limitations. Deficiencies in financing, resource mobilization, budgeting structure and accounting procedures account most importantly for underfunding of maintenance.

47. Globally, the development and maintenance of infrastructural facilities are funded through four principal sources of revenue:-

(a) Grants from central and provincial governments;

(b) Assigned revenues, consisting of taxes and royalities, usually levied by central government but assigned to local governments;

(c) Direct revenue to local governments, consisting of local taxes, service charges, revenues of the functional service departments (e.g., company registration, building permits) and, in the case of centrally planned, non-market economies, such as China, profits from self-administered industries; and

(d) Loans to local government.

Depending on the nature of the infrastructure sector and the extent of central-government control over the sector, a mix of the above sources is used to fund maintenance activities.

48. For a variety of reasons, heavy reliance on central-government subsidies and grants has limited the ability of maintenance departments to channel sufficient funds for maintenance. For example, in 1984, 96 per cent of recurrent expenditure in the city of Minya in Eygpt was met through grants from central authorities. Many governments continue to depend on foreign assistance in providing most of the capital for grant allocation towards infrastructural development and maintenance. For example, 75 per cent of investment in the water-supply and sanitation sectors in the African region is currently met from external sources. External assistance to infrastructure-sector development is predominantly intended for construction, and rarely are funds made available to meet recurrent costs. Foreign assistance agencies have typically been prepared to finance only the cost of equipment for maintenance, which represents only a quarter to a third of total maitnenance costs. Financial problems created by foreign-exchange losses and rate-of-return covenants on loans acquired over the past 10 to 15 years, in the face of declining values of local currency have prevented governments from making sufficient budgetary allocations to cover the remaining maintenance costs. Even where such allocations were initially made, these have subsequently been cutback as a result of initial overbudgeting or used for other pressing priorities. Budget for maintenance is often singled out for cutting back when governments and sectoral agencies need to economize. Limited financial planning with specific target-setting on a multiyear basis has also contributed to present-day mismatches in recurrent expenses and budgetary allocations.

49. Certain infrastructural sectors rely primarily on revenue based on national taxes and royalties for their capital and recurrent expenses. In many instances, such revenues total more than the expenses in that sector, but, even so, it is rare that sufficient funds are made available for the requisite maintenance of the assets that generate this revenue. The road and highway sector is a good example where this misappropriation is common. Revenues from road-users, collected in the form of fuel taxes, license and registration fees, import and excise taxes on vehicles and spare parts, and tolls and fines, in most countries surpass expenditures in the sector and constitute a primary source of revenue to the national government. However, because they are so important, they frequently become a critical part of general-government revenue and find their way into a common national treasury account for use in a multiplicity of sectors. Overcoming the problem of underfunding in such cases must be based on the earmarking of specific taxes for related sectoral development and maintenance efforts.

50. Direct revenue to local government, especially through service charges, property taxes and commercial permit levies, constitute an important source of funds for local infrastructural development and maintenance. There has, for example, been a very positive trend in recent years towards the creation of financially autonomous local agencies for providing telecommunication, electricity, water-supply and sanitation services whose financial self-sufficiency is based on appropriately structured service tariffs recoverable directly

from the users. Tunisia and Brazil are two examples of countries that have gone a long way towards creating such financially autonomous water and sanitation agencies.

51. Equally important for other infrastructural sectors has been the trend to create municipal development funds within urban authorities, through revenue generated from local property taxes and permit levies. Unfortunately, however, many problems still continue to hinder the establishment of full revenue recovery within established agencies. Political opposition to raising taxes and tariffs to appropriate levels, deficiencies in legal mandates to impose charges, inefficient billing and collection procedures, out-dated assessment rates, delayed or delinquent payments or a general lack of civic compliance are some of the common reasons why local resource mobilization has been hindered. Some of these causes were, for example, responsible for poor local revenue generation in Indonesia. Property taxes, which constitute the single most important source of revenue (20-50 per cent) for most cities in the world, account for only 5-10 per cent of the total resources for Indonesian cities 16/. Additional means of local revenue generation, such as parking tariffs and fines for illegal parking, have been little exploited so far. Where profits from local-authority-administered industries have formed the principal source of revenue for capital and recurrent infrastructural expenses, a particular problem has resulted in that, in a bid to increase profits, authorities have given priority to re-investment in industry at the expense of maintaining and expanding existing infrastructural facilities.

52. Ironically, some of the causes of low funding for maintenance is rooted in poor maintenance. High leakage losses and unauthorized connections to piped water-distribution systems, for example, have frequently prevented full revenue recovery for this service.

53. Poor revenue generation directly from users in urban areas, in particular high-income areas, implies that these communities continue to receive subsidized services, which, in turn, results in few funds being available for extension and maintenance work in rural and urban fringe areas. Until high-income urban communities begin to pay the capital, operating and maintenance costs of infrastructural services, in one way or the other, low-income groups cannot be expected to contribute to the running costs of their services. Financial self-sufficiency remains a distant goal for rural communities. Rural needs are often met at low per capita costs, corresponding to low standards of service, but low levels of income and the absence of industrial and commercial users lessen prospects for full cost-recovery. There are, however, encouraging examples in the delivery of water-supply services in many regions, where contributions in kind and assumption of responsibility for operating and maintaining service facilities have been successfully mobilized through community participation. Such community contributions have gone some way towards alleviating the problem; however, substantial capital subsidies are still required from central government or urban users to ensure adequate maintenance of rural infrastructure.

54. Institutional lenders within a country, as a source of sectoral funds, have been largely untapped so far. This is

primarily because a majority of these institutions are relatively undeveloped but also because a majority of the sectoral agencies, with their weak institutional framework and cost-recovery procedures, are still not creditworthy.

F. Inventories and records of assets

55. A common obstacle to systematic planning, budgeting, financing, execution and monitoring of maintenance activities is the absence of adequate records and inventories of assets, indicating their capacity, utilization and condition. Virtually no reliable plans, indicating location, depth below surface and other relevant information, are available for water mains, sewers, drains etc., and as-built drawings of new facilities, which contain such information, are scarcely ever kept safe. Even where infrastructural facilities are visible, such as with roads, few up-to-date records exist which indicate their current extent and condition. Where agencies have attempted to gather such information, they have been obliged to transpose the information onto out-dated base maps which do not indicate the current extent of urbanization. While aerial mapping can often be used to overcome this problem, security restrictions prevent its use in some cases. When no records are available, even the age of exisiting assets remains unknown.

56. Few maintenance agencies have any system in place to record and monitor maintenance history for specific infrastructural facilities. This shortcoming prevents them from approaching maintenance work in a way that they can eliminate the cause rather than the symptoms of trouble-prone infrastructure. It also prevents the monitoring of deterioration trends over time to guide new design and maintenance efforts.

G. Plant, equipment and materials

57. Plant and equipment used in infrastructural systems and services can constitute a large or small component of the total capital asset. For example, 70 to 80 per cent of the total cost of providing a refuse-collection service is devoted to the purchase and operation of collection vehicles, while the capital and operating cost of a pumping station might account for less than 10 per cent of the entire cost of a sewerage system. Whatever the asset value, the uninterrupted operation of plant and equipment is crucial for the continued functioning of the system. Consequently, maintenance is a priority concern.

58. Despite its importance, the maintenance of equipment in most developing countries is poor. There are many reasons for this, not least of which is the inappropriate original choice of equipment. Compactor trucks designed to handle light, dry, unabrasive solid wastes have, for example, experienced frequent breakdowns when introduced in developing countries where the waste is dense, moist and abrasive. There are a number of less-mechanized vehicles which are suited to handle the latter waste.

59. Lack of foreign exchange to procure spare parts and lack of skills and facilities to repair and service equipment have been a further constraint. The efficiency with which fleets of equipment are run at present leaves much to be desired. Rates of availability and use and levels of productivity are extremely low. It is also common to observe the use of vehicles well

beyond their economic life, owing to lack of financing mechanisms and policies for systematic replacement and renewal. Cannibalizing of a portion of a fleet to sustain the remaining fleet units therefore, has become institutionalized.

60. Little, if any, routine maintenance of plant and equipment is undertaken in most countries. Where pumps have not been calibrated for many years, for example, they operate at a third of their potential efficiency. Although, provision is initially made in providing standby equipment to cover failures and to facilitate maintenance, this surplus capacity is frequently lost in a few years owing to poor maintenance.

61. While most maintenance departments are aware of the benefits of standardizing equipment, such as reducing the variety of spare parts, service tools and repair procedures that are required for maintenance, they have, nonetheless, not been able to achieve this objective. Many bilateral assistance programmes have provide attractive terms for financing equipment, and this has, in part, been responsible for the proliferation of equipment, with a wide range of incompatible makes and systems. Much of the equipment purchased has been under a large one-time delivery agreement which prevents a smooth aging pattern that facilitates repair, replacement and renewal. Because most aid agencies have a policy not to fund recurrent expenses, in a bid to encourage local resource mobilization, there has been an unconcious national policy in many countries to allow assets, both facilities and equipment, to deteriorate to a point where replacement becomes the only option for which assistance may be sought.

62. Crucial bottlenecks are caused in juggling different sources of foreign assistance; not all components of infrastructural development and maintenance can be funded, and conflicting demands arise in purchasing equipment from different foreign markets. This was amply illustrated in Guatemala recently 17/. The water authority had negotiated a large Inter-American Development Bank loan for expansion of water supplies and improvement of trunk distribution; it had a Japanese loan for pump and mechanical replacement; and it had a French loan to study maintenance and management needs. In this array of foreign financing, however, there were no funds for maintenance, repairs and small-part replacements. Existing pumping and other equipment was from the United States of America, and the replacement items available from Japan were incompatible with it. Given the lack of funds for maintenance, the authorities might be forced to scrap prematurely still useful equipment, in order to take advantage of the favourable terms of the Japanese loan.

63. Lack of foreign exchange and of knowledge of up-to-date developments in maintenance practices and equipment has prevented governments from obtaining necessary maintenance materials and equipment. Essential imported materials, such as bitumen and water-treatment chemicals, cannot sometimes be obtained. Even the most basic maintenance work requires some form of laboratory testing facility which is unavailable in many countries. Technological advances in maintenance practices and the use of specific equipment, such as interred cable detectors and condüit television cameras which can facilitate and promote maintenance work, have yet to see wide application in developing countries.

III. STRATEGIES

A. Maintenance choice rationale

64. The preceding analysis of the problem of maintenance in developing countries indicates that reforms are required in a number of areas, such as institutions, finance and staffing. The extent to which such reforms are required will, however, be determined by the basic strategy adopted for maintenance. No universal maintenance strategy can be proposed to cover all infrastructural sectors in every country. Sector-specific and location-specific strategies will have to be developed, based on a blend of maintenance options that will maximize the value of maintenance investments. There are seven non-mutually exclusive options 18/ for conducting maintenance work, as follows:-

(a) Only undertake crisis maintenance.

65. Under this option also referred to as emergency or breakdown maintenance, only minimal maintenance is undertaken in response to breakdowns and public complaints. Although this is the cheapest maintenance option in the short term and the most common practice in developing countries, deferring maintenance leads to increasing frequency of breakdowns with age, which, besides increasing costs, reduces service quality and increases interruptions. Continued use of this practice implies little change from the existing situation, and this cannot be the dominant strategy for maintenance, although, in certain circumstances, this option might be the most cost-effective. Such circumstances may include occasions where early interventions to eliminate frequent breakdowns are excessively expensive or where intervention is unlikely to increase asset service life substantially.

(b) Worst first.

66. Under this option, infrastructure-condition assessment and failure-rate information are used as the sole basis for establishing maintenance priorities, with the objective of attending first to that component of infrastructure that is in most need of attention. This option is, therefore, readily applied to visible infrastructural facilities, such as roads, but is difficult to apply to interred facilities, such as water-main and sewer systems. This strategy also relies heavily on the ability of concerned departments to make asset-condition assessments and to maintain failure-rate records. It has, therefore, important implications for the departments ability to secure skilled staff, up-to-date records, inventories of assets and condition-assessment equipment. An advanced interpretation of this maintenance option is to identify the most trouble-prone infrastructure and to undertake a study to establish causes before recommending specific corrective actions. The drawback of this option is that little or no effort is made to compare long-term cost savings and user convenience of other maintenance options which imply early rehabilitation or replacement. For example, it might prove more efficient to undertake preventive maintenance on a slightly deteriorated but heavily used road than to repair heavily deteriorated but infrequently used roads.

(c) Opportunistic scheduling.

67. Under this option, maintenance work is done at least cost and inconvenience to public, by taking advantage of the repairing or replacing of one infrastructural facility to attend to one or more other facilities concurrently. Inspection and repair of a sewer system might be undertaken when attending to other utilities in the same location. The replacement of water mains during street-paving in Minneapolis, for example, was said to have saved 40 per cent of the over-all cost of an independent mains-replacement exercise 18/. Where opportunistic scheduling is co-ordinated, it is possible, for example, to assess the condition of buried pipes the year preceding road resurfacing, in order that those stretches unlikely to last the lifetime of the new road surface can be replaced prior to resurfacing. Implicit in the use of this maintenance option is the need for close interagency (including relevant private agencies) co-ordination of work schedules. The main disadvantage of this option is that maintenance might be excessively deferred in pursuit of such opportunities or replacement made prematurely to take advantage of forthcoming opportunities.

(d) Pre-specified maintenance cycle.

68. Under this option, maintenance work is undertaken in conformity with previously established rehabilitative and replacement cycles, such as, replacing sewer pipes every forty years or painting road lines once every year. Although the concept that all assets need replacement after a fixed time period and specific works done to them periodically is very useful for planning maintenance and future capital investment works, in practice, however, it is impossible to predict infrastructure deterioration. Even where average lifetime standards are determined with precision, rehabilitation and replacement based solely on this criterion will require extra costs since, on average, half the facilities will be prematurely replaced and others will in any case, need attention before the standard lifetime. Other factors beside age influence the life of facilities and deterioration rates established in one country may not apply in another. For example, the corrosive nature of the soil in parts of Saudi Arabia cause concrete pipe to last a quarter to a third their normal lifetime in the United Kingdom. Likewise more road patching will be required during years of heavy rainfall than years of sparse rainfall. Most developing countries will have few lifetime standards. Any values originally assigned for these must therefore be seen as goals which should be iteratively updated in conformity with experience. The need for rehabilitation and replacement to comply with set standard cycles may be judiciously verified through asset condition examination prior to initiating work.

(e) Repair components "at risk".

69. This option has, as its prime objective, the minimization of service disruptions and user inconvenience. Components of an infrastructure facility which are at risk of breakdown are identified and attended to on a priority basis before failure occurs. Operational and physical characteristics (of each component of a facility) that are closely related to, or predict, failure is used to guide appropriate repair, rehabilitation and replacement timing and measures. At-risk priorities are

established based on experience and might, for example, dictate that recently laid pipes with multiple breaks be replaced before very old pipes which show no such problems. While this option has the advantage of substantially reducing future service disruptions, its principal disadvantage is that it does not consider whether the early maintenance measure is worth the future reductions in emergency repair costs, service disruptions and user inconvenience. The adoption of this maintenance option implies the need to maintain failure records, including assessments of potential causes, in order to determine breakdown - prediction characteristics. Implicit in this requirement is also the need for appropriately trained skilled staff.

(f) Preventive maintenance.

70. This maintenance option entails the execution of prescheduled systematic programmes of inspection and relatively low-cost maintenance activities designed to interrupt the deterioration cycle and prolong service life. The objective of this approach is to avoid extensive and costly maintenance during the life of infrastructural facilities and postpone replacement significantly. An example of preventive maintenance is the sealing of road potholes following regular inspection, to arrest deterioration and defer resurfacing. Although conceptually the idea of investing a little on a timely basis in order to minimize large future expenses is indeed a commonsense approach and one that has been confirmed in practice, this option is grossly underutilized. It is likely that this option will form the most cost-effective and, therefore, dominant strategy for most infrastructural facilities in developing countries where labour costs are low. Maintenance problems in sewer systems, for example, are often confined to limited sections of facilities, and low-cost preventive maintenance, such as regular flushing, can prevent blockages. Preventive maintenance can only be cost-effective when costs incurred are small: too much preventive maintenance can be wasteful and, in some cases, harmful, such as by increasing wear on sewer pipes when flushed under pressure.

(g) Reduce wear and tear.

71. This option has as objective the reduction in demand for future maintenance needs and can be achieved through:-

- Undertaking public education programmes to increase civic co-operation in utilizing infrastructure facilities as designed, for example, the avoidance of the discharge of foreign materials into sewer systems or the promotion of the use of car-pools and public transport as a means of reducing traffic congestion and wear on roads.

- Undertaking specific actions to enforce conformity to design standards, such as the use of weighbridges to control axle loads.

- Providing feedback to infrastructural design teams from maintenance monitoring information on alterations in design to reduce maintenance requirements, for example, by changing sewer-pipe materials from concrete to plastic, since the latter is the easiest to clean, requires least maintenance

attention and lasts longest.

- Assuring quality in construction, especially for those components known to create maintenance problems if inadequately controlled during construction, such as pipe-jointing in sewer construction.

72. In order for any of the options for reducing wear and tear to be justified and promoted actively, comparative life-cycle economic costings would be required to illustrate savings.

73. Ideally, an over-all maintenance strategy in a specific country or infrastructural sector should be established through an economic comparison of blends of maintenance options. Economic analysis used for this purpose should be based on life-cycle costs, which include all capital, operating and maintenance costs discounted over the life of the facility, and also aim to quantify the social advantages and disadvantages, such as user convenience and service disruptions. The analysis should also reflect the true cost to national economies of different maintenance strategies and, therefore, reflect the relative abundance or scarcity of resources utilized under each strategy, such as the abundance of labour and scarcity of foreign exchange.

74. In practice, however, such analyses for an entire sector might prove unwieldy, and governments might lack resources, maintenance data and asset records to do justice to this approach. Some degree of simplification of the approach, to match resource and information availability, will be called for when considering the sector as a whole, but efforts must be made to use the approach when considering the choice between rehabilitation or replacement of individual systems. In practice, it is also recognized that the determination of an over-all maintenance strategy is unlikely to dependent exclusively on economic considerations and will be significantly influenced by the ability of governments to introduce necessary reforms in corresponding functional areas within each sector. For example, there is little point in defining a maintenance strategy based primarily upon opportunistic maintenance, if the corresponding interagency co-operation cannot be secured. Principal strategies for reforming functional areas, including institutional structure, maintenance management, staffing and training, and finance, with the aim of improving maintenance performance are defined below.

B. Institutional reforms

75. Any reforms to existing institutional arrangements undertaken without concomitant adjustments to, inter alia, financing and staffing of these institutions will have but a limited impact on maintenance. Adjustments to institutional structures should, therefore, be considered in conjunction with others to financing and personnel systems. The principal objective of institutional reform should be to pin responsibilities precisely through the creation of specific sectoral agencies and the establishment of separate maintenance units within each agency with clear legislative mandates and comprehensive, yet distinct, jurisdiction to undertake all maintenance functions, including policy formulation, planning, financial-resource mobilization and execution.

76. While maintenance units should be entrusted exclusively with maintenance responsibilities, their operation can only be effective with the necessary vertical ties and links within the sector-specific ministries. This is required primarily for ensuring that adequate programmes of maintenance which are responsive to contemporary local, sector-related needs are developed and that sufficient funds are generated or allocated for their execution. The structuring of the maintenance units and their vertical integration within a sector should reflect the importance of infrastructural maintenance which should, in turn, be visible in over-all sectoral plans. An indication of the prominence assigned to maintenance might be gleaned by comparing resource allocation between construction and maintenance operations and the percentage of sectoral asset-values devoted each year to maintenance purposes. In this context, it must be recognized that biases against maintenance can only be overcome by convincing decision-makers that maintenance warrants priority attention. Relevant economic, social and technical arguments, based broadly on those identified in Section I of this paper, can be developed for each sector, to reinforce the point in specific country contexts. Institutional structures should also permit close collaboration between design and maintenance divisions in a way that permits a two-way flow of information.

77. The economic and operational efficiency of maintenance work will be directly proportional to the extent of relevant inter-sectoral co-ordination that governments are able to institute. Consideration should be given to the identification of common work schedules, equipment, plant, materials and labour utilization, and procedures instituted whereby these may be optimized through co-ordinated intersectoral activities. Given the considerable amount of capital tied up in equipment and plant and the need to maximize their utilization, the merits of creating divisions with autonomous budgets and of charging rentals to field divisions require examination. Such an arrangement has functioned successfully for road maintenance in Malawi.

78. It is imperative that institutional structures for maintenance be responsive to local needs. This can only be ensured through a decentralized institutional structure, the extent of which will vary from sector to sector. Generally, decentralization in the form of "deconcentration" from central to local agencies is called for, which, in the case of rural water supply and sanitation, might be required to extend to community groups and organizations. Adequate provision should be made to ensure that such linkages are strengthened and operationally institutionalized. A principal consideration in determining the extent of "deconcentration" is to limit the spreading of qualified staff and equipment resources too sparsely to be effective. Equally, the extension of an institutional structure to include community groups is precisely for purposes of mobilizing resources within communities which would otherwise not be forthcoming. Experience has confirmed that, where appropriate institutional and financial management systems are in place, communities are able to assume responsibilities for operation and maintenance.

79. One matter for close scrutiny is the size and nature of maintenance units. It is essential that efforts be made to

optimize maintenance efficiency and improve institutional accountability and performance through a sharing of maintenance work with private contractors. Where an active policy of private-sector participation is pursued, the task of maintenance units will change from the management of labour equipment to supervisory functions, which would require them to be endowed with staff suitably skilled in these duties. While periodic and rehabilitative maintenance work and the supply of quantifiable materials and services can be readily described in contractual terms and can be easily contracted out, emphasis needs to be given to the parcelling of routine, corrective and preventive maintenance work for contracting: unit-price-rate and cost-plus types of contracts may be used for this purpose. The contribution of small-scale contractors in maintenance has been underutilized, and there is scope for assigning routine, corrective and preventive maintenance work to these entities under competitive bidding terms.

C. Maintenance management

80. The first step to improving maintenance is to develop a multiyear maintenance management plan, incorporating policies and strategies that align proposed work schedules with corresponding resource-mobilization propositions. Approaches to financing infrastructural developments dictate that such a maintenance plan should not be seen in isolation from but form an integral component of an over-all sectoral development plan. This not only is essential to redress imbalances between capital and maintenance investments but is fundamental for establishing reforms in institutional arrangements, staffing and financing, consistent with over-all sectoral development policies.

81. The principal objective of a maintenance plan is to define the most economical and practical blend of maintenance options and requisite work-schedules responsive to sectoral needs. In order to do this it is necessary to assemble records of assets, indicating extent, age, capacity, utilization and condition. Where this information is not readily available, the extent, age and capacity of infrastructural networks and facilities should be obtained through field surveys and transposed onto an up-to-date base map. Sampling techniques may be used to assess the utilization and condition of the networks and ancillary facilities. The experience of existing maintenance teams in identifying "trouble spots" will prove invaluable during this initial survey. It will also be necessary to define basic criteria, such as, roughness or percentaged "pot-holed" area for the road sector for example, to classify the condition of infrastructure; and traffic or sewage flow rates to indicate utilization. Consideration should be given to the use of specialized condition-assessment equipment and relevant asset-deterioration indicators identified through recent research. With this information, it will be possible to define work schedules and corresponding combinations of maintenance options. In many cases, this initial survey will determine the scope, scale and cost of rehabilitation works required to eliminate existing backlogs of deferred maintenance: it is, however, important that the plan also take steps to prevent other assets from reaching the stage where rehabilitation is necessary.

82. It will be necessary to define mechanisms for resource mobilization and align resources with worldload so that inputs

are delivered in a timely fashion. While such a plan might be far from the economic optimum, it will, in the face of inadequate maintenance information, form the first step of an iterative plan.

83. Although initial maintenance plans will, by necessity, be based largely on judgement, it is essential that information and management systems be introduced for estimating costs and assessing performance in order to guide future plans, improve operational efficiency and provide feedback for future infrastructure design. Experience suggests that it is prudent to make such systems as simple as possible, eliciting only information which is vital, and gradually develop them into a full-scale management information system. One area which defies simplication is the compilation of inventories of assets. These will have to be developed comprehensively, and systems will have to be introduced for safe storing and retrieval of this information and of as-constructed drawings of new facilities as they are completed. Appropriate management systems are required for (a) materials control; (b) records of release, service, usage and maintenance of equipment; (c) records of maintenance requests and problem diagnoses; (d) workorders and daily work reporting; (e) contract monitoring and supervision; and (f) financial control.

84. The objective of introducing management systems is not to obtain the required information per se but rather to translate this information into performance criteria that will enable the identification of system bottlenecks and permit the assessment of productivity. For example, where vehicle utilization rates, determined as the number of actual worked hours per year, are low, it might lead management to hire vehicles in future. Where labour productivity or work quality is noted to be poor, field inspection and supervision might be intensified. Over-all cost analyses of completed maintenance work will, in some cases, suggest that contracting work might be more economical than undertaking it in-house. Likewise, an analysis of the causes of delays in attending to specific maintenance requests might identify problems in the availability of essential material or spare parts. While such performance criteria will serve to improve operational efficiencies, it is equally important to develop maintenance quality standards, such as composition of slurry for sealing concrete roads, lining cast-iron pipes etc., in a way that will balance investments in maintenance with the potential benefits of improved service, prolonged asset life etc.

D. Staffing and training

85. Utilizing the work schedules defined in the multiyear maintenance plan, it is possible to define the minimal number of positions required at each level of the institutional structure to execute the plan. Such positions should be established with corresponding "job descriptions" to address all functions demanded by the plan. The delegation of responsibility to each position should be rationalized to avoid overlaps and conflicts but include essential reporting functions. The next step would be the preparation of an inventory of existing manpower within the maintenance units indicating the qualifications and experience of each staff member. A comparison of this inventory with the positions defined will help identify gaps and surpluses in manpower distribution. Similarly, matching experience and

qualifications of staff with those defined in each job description will help identify skill gaps and suggest training needs. The final step is to align staff size and skills with those demanded by the maintenance management plan. Clearly, as the management plan is dynamic, some changes in staff size and skills will become necessary with time, as management strives to improve maintenance productivity.

86. From the preceding assessment of training needs it will be possible to define a training programme which will be sufficient to meet the initial need for skilled personnel and be able to cope with future demands likely to be exerted through staff turnover, promotions, rotation, retirement etc. Experience suggests that such training programmes will need to be institutionalized as an ongoing activity, through the creation of a training unit within maintenance departments. While training might first concentrate on planning, supervision and quality control, it would also need, to focus on developing skills in communications, community development and public relations. Training programmes must take note of the key role that supervisors play in ensuring the success of maintenance programmes: besides guiding and controlling the quality of work and being responsible for enforcing safety, inventory and cost control, they are also responsible for over-all operating efficiency through motivation of supervised staff. Another requirement of which training will usually need to be focused is maintenance-need assessment: even where such assessment work is contracted out it will be essential to have staff in-house who can monitor and evaluate the validity of assessments.

87. Despite the need to define a training strategy that gives due priority to groups of personnel, such as supervisors, the training programme should be as comprehensive as possible in the personnel it covers. Training techniques which are based on short courses and seminars, followed by in-service practice have the greatest potential. Learning by mistakes and achieving expected quality standards under close supervision have proved a particularly successful way of training maintenance crews. Alternative training techniques, based on seminars, workshops and discussion groups, are required at supervisory and managerial levels. A mode of training which has particular application for plant and equipment maintenance is the conducting of supplier courses: agreements to conduct such courses may be included in contracts for machinery procurement. Yet another form of training which has proved effective, especially under bilateral aid agreements, is the twinning of related sector agencies or research institutions in developed and developing countries, whereby maintenance techniques, assessment methods and inventory and record-keeping systems have been transferred from one country to another. A successful example of such training in the water sector is an agreement signed in 1982 between Anambra State Water Corporation in Nigeria and the Southern Water Authority in England.

88. While training is clearly important in improving maintenance, it will only have a limited impact unless accompanied by incentives in salary and status related to good performance. Good career development prospects, including possibilities of accelerated promotion, realistic salaries and incentives, will be essential for attracting and retaining competent staff. Increased prominence will need to be accorded to those engaged in

maintenance work especially in over-all running of the agency. Efforts must also be devoted to increasing the visibility of maintenance units, through the use of logos on vehicles, attractive uniforms, protective gear and safety equipment.

E. Finance

89. The key to improving maintenance lies in making available sufficient funds to finance all planned activities and operations. Implicit in this requirement is the need to improve the fiscal base of units entrusted with maintenance responsibilities, through appropriate revenue-generation mechanisms. The first step towards improving maintenance financing must, therefore, be the undertaking of a review of possible sources and modes of revenue generation, followed by the provision of the necessary legal and institutional means for revenue collection. While the structure and arrangement of sectoral institutions and the nature of political systems in place will, to a large extent, influence the choice of revenue sources and modes of generation, it is possible to define strategies that will maximize the efficiency of revenue raising for maintenance.

90. The primary requirement of such a strategy is to recover, as far as possible, the entire cost of maintenance directly from beneficiaries in proportion to their consumption or measure of benefit accrued. This requirement implies a high level of decentralized financial autonomy. For example, the maintenance cost of a water-supply system for a city is best recovered at the city or local level and should be charged in proportion to quantities consumed. It is, however, not always possible to apportion infrastructural facilities to specific beneficiaries and questions of equity might prevent the recovery of the total cost of maintenance from certain groups within a community. Therefore, as a second requirement, those costs which cannot be recovered through direct charges should be recovered through taxes: in keeping with the first requirement, however, such taxes should be levied and generated locally. For example, urban roads and stormwater drainage maintenance expenses may be recovered through property, business and other similar local taxes. The fact that certain infrastructural facilities are transterritorial implies that any effort to align maintenance costs with beneficiaries necessitates the intervention of higher-level government and the levying of nationwide taxes. For example, highway maintenance costs which cannot be recovered through direct user charges, such as toll-gate charges, could be obtained through a national tax on fuel. The above three-tier strategy, based on a bottom-up approach to revenue generation and aimed at strengthening local-government finance. should form the basis of maintenance financing.

91. Consistent with the above maintenance-financing strategy, the initial step should be to identify appropriate sources of direct revenue to local authorities. User-charges and local taxes form the obvious sources of direct revenue, and these should be maximized. Depending on the nature of the infrastructural facility, two types of user-charges may be applied - consumption-related and benefit-related. Consumption-related charges apply readily to facilities, such as water supply, electricity supply, sewerage and telecommunication. Infrastructure-maintenance expenses comprise only a small

proportion, usually less than 15 per cent, of the total needed to finance capital, operating and maintenance expenses. The need to recover, through user-charges, capital and operating costs in addition to maintenance costs usually results in the levying of an over-all charge that incorporates all three elements. It is, therefore, essential that, where user-charges are a mode of financing maintenance work, the corresponding maintenance cost is adequately and integrally reflected in the over-all charge and, most importantly, that the proper proportion of the over-all revenue is allocated exclusively for maintenance activities. The maintenance of sidewalks, roads and stormwater drainage systems can, in whole or part, be financed through the levying of a "betterment" tax on contiguous properties. In order for such a system to work, however, local authorities will require the co-operation of the community, and this approach is likely to be most successful in areas with well-organized community organizations working closely with local authority staff trained in communications and community-development skills. In kind inputs, such as labour, may be used to reduce tax values in low-income areas.

92. While consumption-related charges can often adequately raise the entire sum necessary for maintenance work, it is unlikely that betterment taxes can do likewise. That proportion of maintenance expenses which cannot be recovered through direct user-charges are best met through local taxes, fines and profits. Property taxes and business licences form the principal sources of local taxes, but many reforms are required before these sources can provide substantial recurrent receipts for both capital and maintenance investments in infrastructure. Improving property records or cadastres, updating assessment records, improving billing and collection procedures and providing legal mandates to set and enforce charges are some of the reforms commonly necessary before local tax returns can be improved. The case of Delhi, India, suggests that efforts invested in such reforms are worthwhile: improved collection procedures - including penalties for late payment and rebates for prepayments and an improved management information system - served to increase revenue by 96 per cent between 1986 and 1987 20/. Where local authorities are empowered to impose automobile taxes, these can also form a useful source of local revenue. The imposition of parking tariffs and fines for illegal parking can provide additional revenue and should be exploited wherever possible. Depending on anticipated annual revenues from specific taxes and fines, it is essential that efforts be made to identify individual taxes and allocate all the proceeding of these taxes or a proportion thereof exclusively for corresponding sectoral maintenance works. This calls for the creation of separate accounts for each sector to which taxes may be channelled. The funds from such accounts should only be usable by public works departments exclusively for maintenance purposes. Where it proves impractical to assign set taxes specifically for maintenance purposes and maintenance expenses are most easily retrieved from a general local-government coffer, earmarking of funds exclusively for maintenance must, in such cases, form an essential follow-through activity. The earmarking principle is especially important where profits from local-authority-administered industries are used to fund maintenance work.

93. While the strategy for efficient resource mobilization for infrastructure maintenance advocated above is primarily aimed at increasing local-government capacity to generate revenue, there are instances where this might not be possible. Some form of national-government grant might be necessary when facilities serve transterritorial beneficiaries, when subvention is required to meet low-income population needs and when deficits in local revenue generation occur. These grants might be generated through national taxes and royalties or through state profits from trade surpluses. The latter is rarely the case in developing countries, and, even when surpluses do occur, competing priorities of other social sectors, such as education, imply that little if any precedence will be accorded to funding infrastructural maintenance work. In addition, the unreliability of trade surpluses, which vary widely from year to year, impedes programmed maintenance. Reliance on trade-surplus-generated grants should, therefore, only be adopted as a last resort.

94. Intergovernmental allocation of grants, generated through national taxes and royalties, can form a useful means of overcoming deficits in maintenance funding. In order that governmental commitment to infrastructural maintenance is translated into practice, it is essential that, as in the case of local taxes, revenues from specific taxes or proportions thereof be allocated to sector-specific maintenance funds. This approach has, for example, been adopted in Paraguay to finance highway maintenance, where 10 per cent of the revenue from fuel taxes and a special surcharge on imports have for many years been effectively directed, in equal monthly instalments over the fiscal year, to a special account for road-maintenance operations 4/. Similarly earmarked tax revenues could be identified to cover all infrastructural sectors. This approach is a more effective alternative to earmarking accumulated tax funds from a general national coffer and is fundamental in assigning maintenance due priority and continuous funding.

95. Infrastructural maintenance - in particular rehabilitative maintenance projects - have demonstrated considerably higher rates of return on investment than new construction. As such, they are attractive for funding through borrowings. Two sources of funds might be used for borrowing: first, it is possible that borrowings can replace intergovernmental grants, and local governments might be able to borrow from central government: secondly, merchant banks can provide an alternative source. However, a prerequisite for either of the two forms of borrowing is the institution and operation of sound cost-recovery procedures. Such an approach of including the participation of merchant banks in funding the upgrading of infrastructure in the States of Benue and Gongola in Nigeria is expected to be initiated in the near future 21/. Under the project, training will be provided to officers of five merchant banks to undertake rigorous technical and financial appraisals prior to approving projects for funding. The alternative approach of central-government lending to local governments for infrastructural development works is widely practised in countries such as Brazil. The approach of borrowing, when coupled with reforms to local-government revenue generation, can form a useful means of raising sufficient funds to meet initial backlogs in rehabilitative maintenance work.

IV. THE ROLE OF GOVERNMENTS AND THE INTERNATIONAL COMMUNITY IN IMPROVING INFRASTRUCTURE MAINTENANCE

A. Role of government

96. The problems which have led to unsatisfactory maintenance of infrastructure in several countries can be resolved or, at least, reduced if the appropriate framework for improvement is provided at the national level. Some of the constraints in relation to inadequate funding, faulty management practices, low-priority status and gaps in institutional set-up have either legislative or multiagency co-ordination implications that can be effectively handled only at the national level. In some cases, there can be marked improvements if existing maintenance units upgrade their management techniques, introduce new systems and expand resource capacity and revenue bases. The primary task for a country in need of solutions is to accord priority to maintenance and identify needs and, then, apply innovative methodologies and technologies effectively. To facilitate this approach, national governments can provide a framework to meet requirements for maintenance by focusing on the following measures.

1. Legislative reforms

97. National governments can remove existing legislative barriers which impede effective response to infrastructure maintenance by:

(a) Establishing a national task force or designating an appropriate agency to review all legislative instruments connected with infrastructure maintenance with the view to either deleting or reformulating inappropriate laws and promoting new legislation so as to achieve desired standards of maintenance;

(b) Undertaking frequent periodic reviews of user-charges and levies related to infrastructure; and

(c) Instituting appropriate levies or taxes specifically for infrastructure maintenance or, alternatively, delegating such legal mandates to local authorities or respective agencies concerned with funding infrastructure maintenance.

2. Manpower development

98. National governments can promote local skills required to improve maintenance of infrastructure by:

(a) Incorporating aspects of building and infrastructure maintenance in curricula of institutions training professionals, technicians and artisans in construction - related disciplines;

(b) Establishing in-service or on-the-job training schemes for all grades of manpower in existing maintenance units; and

(c) Introducing new short-courses for specific skills in selected local institutions.

3. Finance

99. National governments can minimize the problem of inadequate funds for effective maintenance operations by:

(a) Reviewing existing sources of revenue, exploring new sources that may be tapped especially at the local levels directly from the beneficiaries and instituting and strengthening such revenue generation mechanisms; and

(b) Improving budgetary and accounting procedures, in particular, to ensure that necessary funds are earmarked and allocated into specific accounts for infrastructure maintenance.

4. Institutional adjustments

100. National governments can provide the appropriate institutional framework required for efficient infrastructure maintenance by:

(a) Incorporating maintenance in national development planning and according this element of respective sector activities the necessary priority it deserves;

(b) Upgrading status of agencies concerned with maintenance and streamlining procedures for effective inter-agency and intra-agency co-ordination;

(c) Deconcentrating maintenance responsibilities in direct response to local needs; and

(d) Establishing due procedures to harness private sector participation in maintenance activities.

5. Equipment and materials

101. National governments can ensure efficiency in maintenance through the provision of suitable equipment and materials by:

(a) Facilitating access to externally-procured, appropriate machinery, equipment and other accessories;

(b) Establishing procedures for different maintenance units to collaborate in the use and repair of machinery, vehicles and equipment; and

(c) introducing simple management systems for stock control and accountability for equipment and materials.

B. Support from the international community

102. Some of the resources required by national governments to establish national maintenance capabilities are beyond the reach

of developing countries and can commonly be provided with the support of the international community. The transfer of know-how on appropriate maintenance technologies and related maintenance management systems, for instance, is of crucial importance in the overall strategy to revamp infrastructure maintenance, but this is one area which cannot be promoted successfully without international co-operation. Some of the technologies and management systems required in developing countries are, to a large extent, already in existence, so that efforts in international co-operation could be made most effective by focusing on transferring and applying know-how rather than developing new techniques. A framework for international support, which facilitates this approach, can be defined by including the following actions:

1. Information flow

(a) Assisting in the preparation and publication of guidelines and information kits addressing specific areas of maintenance such as diagnostic assessment methodology; management systems; utility mapping and record keeping; and standards, procedures, materials and equipment usage; and

(b) Providing basic audio-visual equipment to be used for disseminating maintenance information.

2. Manpower Training

(a) Assisting with bilateral training programmes based on the principle of institution twinning arrangements;

(b) Providing fellowships for on-the-job training; and

(c) Providing resource support in running national or regional seminars and workshops on selected themes.

3. Adjustments in aid policies

(a) Reflect the significance of maintenance and balanced construction/maintenance investments in policies and programmes of donor countries and international aid agencies;

(b) Providing additional and comprehensive aid packages for infrastructure maintenance; and

(c) Priority and due flexibility in the supply of only those equipment that are truly responsive to local needs and within the means of responsible agencies to operate.

4. Co-ordination of international efforts

103. Concerted efforts at the national and international levels will be required to meet demands for infrastructure maintenance as decision-makers become more aware of the importance of maintenance. The international community in particular will have to support the expansion of research and development programmes

UNCHS (Habitat) is prepared to undertake a co-ordinating function, by selecting useful experiences and documenting findings for dissemination to member countries and also co-ordinate specific national programmes in this endeavour. In order to achieve this function, UNCHS (Habitat) will require additional support from the international community, namely to:

(a) Provide resource inputs for technical publications on infrastructure maintenance; and

(b) Establish demonstration projects aimed at introducing appropriate methodologies and technologies for infrastructure maintenance.

ANNEX 1 - DEFINITION OF MAINTENANCE TERMS

1. Preventive maintenance - systematic and prescheduled programme of inspection and low-cost maintenance activities aimed at early detection of defects and interruption of asset deterioration cycle.

2. Corrective maintenance - maintenance activities undertaken in response to breakdowns or detected defects.

3. Routine maintenance - preventive and corrective maintenance activities involving small-scale interventions undertaken on one or more occasions each year.

4. Periodic maintenance - large scale, infrequent maintenance activities usually undertaken at predetermined cycles of more than one year.

5. Rehabilitative maintenance - maintenance activities undertaken to correct major defects and wear and tear in order to restore asset to its original functional capacity and physical condition.