TRANSPORTATION TECHNOLOGY SUPPORT
FOR DEVELOPING COUNTRIES

SYNTHESIS 1

Maintenance of Unpaved Roads

prepared under contract AID/OTR-C-1591, project 931-1116,
U.S.Agency for International Development

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Notice

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Cover photo: Ditch maintenance (Ghana).

Contents

Project Description

The development of agriculture, the distribution of food, the provision of health services, and the access to information through educational services and other forms of communication in rural regions of developing countries all heavily depend on transport facilities. Although rail and water facilities may play important roles in certain areas, a dominant and universal need is for road systems that provide an assured and yet relatively inexpensive means for the movement of people and goods. The bulk of this need is for low-volume roads that generally carry only 5 to 10 vehicles a day and that seldom carry as many as 400 vehicles a day.

The planning, design, construction, and maintenance of low-volume roads for rural regions of developing countries can be greatly enhanced with respect to economics, quality, and performance by the use of low-volume road technology that is available in many parts of the world.

In October 1977 the Transportation Research Board (TRB) began this 3-year special project under the sponsorship of the U.S. Agency for International Development (AID) to enhance rural transportation in developing countries by providing improved access to existing information on the planning, design, construction, and maintenance of low-volume roads. With advice and guidance from a project steering committee, TRB defines, produces, and transmits information products through a network of correspondents in developing countries. Broad goals for the ultimate impact of the project work are to promote effective use of existing information in the economic development of transportation infrastructure and thereby to enhance other aspects of rural development throughout the world.

In addition to the packaging and distribution of technical information, personal interactions with users are provided through field visits, conferences in the United States and abroad, and other forms of communication.

STEERING COMMITTEE

The Steering Committee is composed of experts who have knowledge of the physical and social characteristics of developing countries, knowledge of the needs of developing countries for transportation, knowledge of existing transportation technology, and experience in its use.

Major functions of the Steering Committee are to assist in the definition of users and their needs, the definition of information products that match user needs, and the identification of informational and human resources for development of the information products. Through its membership the committee provides liaison with project-related activities and provides guidance for interactions with users. In general the Steering Committee gives overview advice and direction for all aspects of the project work.

The project staff has responsibility for the preparation and transmittal of information products, the development of a correspondence network throughout the user community, and interactions with users.

INFORMATION PRODUCTS

The two major products of this project are compendiums of previously published information on relatively narrow topics and syntheses of knowledge and practice on somewhat broader subjects. Compendiums are prepared by project staff at the rate of about 6 per year; consultants are employed to prepare syntheses at the rate of 2 per year. In addition, proceedings of at least 2 international conferences on low-volume roads are prepared and transmitted to the project correspondents. In summary, this project aims to produce and distribute between 20 and 30 publications that cover much of what is known about low-volume road technology.

News about the project work is published in the bimonthly *Transportation Research News*; reprints of these articles are distributed to the project correspondents.

INTERACTIONS WITH USERS

A number of mechanisms are used to provide interactions between the project and users of the information products. Review forms are transmitted with each publication so that recipients have an opportunity to say how the products are beneficial and how they may be improved. Through visits to developing countries, the project staff acquires first-hand suggestions for the project work. Additional opportunities for interaction with users arise through international conferences in which there is project participation and through informal meetings with U.S. students who are from developing countries and who attend the annual TRB meeting.

Foreword and Acknowledgments

This publication is the first in a series of syntheses being produced by the Transportation Research Board's project on Transportation Technology Support for Developing Countries. A list of all project publications that have been completed to date appears on the inside back cover of this book.

It is planned that each synthesis be published first in the English language and that separate French and Spanish versions be published as soon thereafter as the respective translations can be completed.

The objective of the book is to provide useful and practical information for those in developing countries who have responsibility for the maintenance of unpaved roads. Feedback from project correspondents will be solicited and used to assess the degree to which this objective has been attained and to influence the nature of later syntheses.

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Introduction

The project on Transportation Technology Support for Developing Countries was undertaken to enhance rural transportation in developing countries by providing improved access to existing information on the planning, design, construction and maintenance of low-volume roads. Nearly all low-volume roads in developing countries are unpaved. The purpose of this synthesis is to bring together the best of the current state of the art for maintenance operations on unpaved roads.

A principal objective is to present clearly the most effective work methods and procedures for individual maintenance operations. But experience has shown that knowledge of good work methods does not necessarily assure an effective maintenance program. National highway agency practices for organization and management of individual maintenance programs are equally as important as the work methods. Therefore the synthesis will also provide guidelines for the planning, scheduling, and control of programs.

The synthesis is thus directed to virtually all levels of highway agency organization; i.e., top-level administrators who are responsible for policy making, organization, planning, budgeting, and allocation of resources, as well as field engineers and supervisors who are responsible for actually doing the work.

Chapter I discusses some of the problems commonly experienced by developing countries in attempting to carry out road maintenance programs. The purpose is to make the reader aware of these unique problems and their consequences, as well as some ways in which the problems can be overcome.

Chapter II briefly describes the typical maintenance functions that are normally required for unpaved roads. The purpose is for the reader to understand the terminology used, the conditions to be corrected, and the general criteria for performing the work.

Chapter III discusses typical practices of highway agency organizations for road maintenance, including general authorities and responsibilities at the various organizational levels.

Chapter IV outlines various management practices for planning, budgeting, and controlling maintenance programs with special emphasis on practical applications in typical developing countries.

Chapter V explores effective utilization of tools and equipment, as well as practices for managing fleets of mechanized equipment.

Chapter VI provides detailed descriptions of generally accepted work methods for individual maintenance activities. Alternative approaches are presented for work methods using mechanized equipment and for methods involving principally hand tools and labor.

It is the intent of this synthesis to provide highway agencies in developing countries with guidelines for carrying out maintenance programs effectively, based on the best of current practices and technology. However, conditions and road system characteristics vary considerably among different countries and highway agencies, and alternative maintenance practices often may be appropriate for particular local conditions. Each individual national agency should consider the alternatives presented and adopt those policies and practices most appropriate for their own use. Some criteria for evaluating the various alternatives discussed in the synthesis are included.

CHAPTER I

Overview of the Problems

Highway agencies in even the most developed countries often have difficulties in carrying out effective highway maintenance programs. As motor vehicle traffic has increased in weight and numbers, the benefits resulting from continuing proper levels of road maintenance service have become apparent. Effective systems, procedures, and practices have evolved. This report draws upon effective approaches that were chosen from the practices of many agencies throughout the world. It does not intend to suggest that these practices may be applied without modification to specific local conditions in developing countries.

Motor vehicle transport has expanded rapidly in recent years in most developing countries. Extensive road construction programs have been undertaken, often with foreign funding assistance. However, in many cases, road maintenance is so inadequate that even newly constructed roads are deteriorating far more rapidly than would normally be expected.

The experience of officials in developing countries in planning and managing extensive road maintenance programs is limited to a relatively short period of time, often under trying conditions. In many developing countries there is also an acute shortage of qualified manpower both at the administrative and technical levels. But there is a considerable volume of experience available from the more developed countries to guide maintenance organization and operations. It is important to remember that some of the problems commonly encountered are unique to developing countries, and that some adjustments may be necessary when applying the experience of more developed countries. Some basic problems in road maintenance and some possible solutions will be discussed in this chapter.

LABOR-INTENSIVE WORK PRACTICES

Developed countries usually strive for as much mechanization of maintenance operations as possible. The primary reasons are that labor is relatively expensive and productivity can be increased with suitable equipment, properly used. The opposite is usually the case in developing countries. The equipment itself and its operation are proportionately more expensive, particularly in terms of foreign currency, and labor is relatively inexpensive. Also unemployment often is a continuing problem, and it is often in the national interest to encourage the utilization of manpower as much as possible.

Thus it is not feasible to accept automatically the work methods and procedures employed in more developed countries. Those maintenance operations which can and should be performed with manual labor and small tools must be investigated and clearly defined. In addition, decisions must be made as to which operations will result in significantly greater productivity or higher quality of workmanship if mechanized equipment is used. These decisions should then be clearly documented so that they can be uniformly and consistently applied. Chapter VI will describe some specific examples of manual labor compared with mechanized equipment maintenance work methods for unpaved roads.

MAINTENANCE VS. CONSTRUCTION

Whenever there is a question of allocating available funds for maintenance work or construction of new roads, construction of new roads usually wins. Two factors contribute to this situation. New construction has much more appeal and offers greater satisfaction to highway engineers than does routine maintenance, and political pressures outside or within the highway agency often influence decisions for new construction projects.

One other problem often arises. Although some new construction is performed by non-government contractors, frequently construction work is done by field work forces from the highway agency. Usually these same agency work forces also are responsible for maintenance. In the day-to-day scheduling of the field forces, this often results in the neglect of needed maintenance work in favor of construction or rehabilitation operations.

Several administrative actions or combinations of actions might help to alleviate this problem:

1. A firm commitment by the government and the highway agency that road and bridge maintenance will have first priority and that funds earmarked for that purpose will not be diverted to other uses is necessary.
2. Expenditures for construction and rehabilitation work will be limited to those available funds in excess of maintenance requirements.
3. Almost all construction work will be performed by private, non-government contractors. Agency work forces will perform only maintenance operations.
4. If agency work forces are to perform both maintenance and construction work, separate organizational units should be established with separate direction and supervision so that maintenance efforts are not diverted to construction.

NONSYSTEM WORK

A national road system usually is established in developing countries to identify those routes and road sections for which the national highway agency has maintenance responsibility. Responsibilities for less important roads and streets not part of the national system are delegated to local governmental jurisdictions.

Resources are allocated to the national highway agency based on the requirements for national roads. Unfortunately, local governments seldom are able to maintain their own roads and streets and exert pressure on the highway agency forces to perform both maintenance and construction work on the local facilities. Often the pressure to do this local work includes nonpublic roads and streets and other facilities.

Obviously the national roads cannot be adequately maintained when national resources are diverted to local work. The options are (1) to establish and enforce policies limiting highway agency forces to work on the designated system, or (2) to make the national agency responsible for all roads and streets (with the possible exception of principal cities) and to provide the additional resources needed by the highway agency for the expanded workload.

NONMAINTAINABLE ROADS

In nearly all developing countries there is one common characteristic of the road systems. Many road sections are in fact nonmaintainable by those operations normally considered as maintenance. This situation is brought about by one or two conditions: (1) there has been a lack of maintenance on the sections for so long that the condition has deteriorated to the point where normal maintenance cannot provide an acceptable level of service; or (2) the road section was never really constructed in the first place; it just grew from a trail with no planned alignment, grade elevation, drainage, or surfacing. Some of these road sections can be reasonably maintained during the dry season, but become impassable during wet periods. When this condition extends over a considerable period of time, severe problems arise in the transport of locally produced materials to markets.

Regardless of the cause, the time and resources spent on maintaining these roads have little effect. Many developing countries, some with foreign funding assistance, are identifying these sections and are undertaking programs of minor construction and rehabilitation to make these roads maintainable. Only then can a normal maintenance program be carried out with satisfactory results.

EQUIPMENT AVAILABILITY

Developing countries commonly experience difficulty in assuring that suitable maintenance equipment is available where and when it is needed. In some cases quite extensive equipment acquisition programs exist. However, the types and numbers of equipment purchased sometimes do not reflect actual maintenance needs. Units on hand may be unsuitable or obsolete. Equipment preventive maintenance and repair practices may be inadequate. Lack of spare parts seems to be a universal problem. Plans for distributing equipment among field units often are not flexible enough to allow the most effective utilization. Records of equipment location and availability may be non-existent, or field supervisors may be reluctant to release equipment, even though it is used only occasionally in their specific areas. Equipment may be available, but financial conditions are such that fuel and oil cannot be purchased.

Responsible officials in many developing countries have the idea that acquiring a large equipment fleet will solve their maintenance problems. But the problems can be compounded with a large fleet unless some type of comprehensive management system is effectively employed to assure that equipment is available and can be economically operated. Some generally accepted equipment management practices are described in Chapter V.

MATERIALS QUALITY CONTROL

Except for foreign-funded construction projects where quality controls for materials are built into the agreement or contract provisions, in many developing countries there is very little knowledge of or consideration for the quality of materials used in road construction and maintenance work. Furthermore, the controls may not be observed during construction. Subsequent maintenance requirements usually are greater if proper quality control is not exercised.

This problem of quality control applies to almost all the materials that are normally encountered in road and bridge work. For the purpose of this synthesis, the concern is principally with the materials in the roadbed and surface of unpaved roads. Further discussion of these problems is included in Chapter VI.

WORK PROGRAMS AND BUDGETS

In developing countries annual maintenance work programs seldom are spelled out in any detail. Budgets if any usually reflect estimates of the manpower, equipment, and materials that will be used, based principally on the previous year's experience. There is no indication of how these resources are to be used, other than to maintain roads.

Without any documentation or communication of specific maintenance objectives, there is no way to evaluate the effectiveness of the field operations. Control may be exercised over funds that are authorized, but there is little or no control over whether or not the work is actually performed. It is essential that a developing country be committed to the concept of an annual maintenance work program for each field organization, with the kinds and amounts of work clearly defined. The budget should delegate funds to specific work to be accomplished as spelled out in the program.

The planning, budgeting, and control of maintenance programs are discussed in more detail in Chapter IV.

MAINTENANCE FUNDS

Developing countries typically have unusual difficulties in providing adequate funds for an effective maintenance program. This is particularly true in the case where foreign exchange is required for equipment, parts, supplies, fuel, oil, and other materials that are not available locally. Furthermore, problems can arise even with local funds. Sometimes the approved budget appears to be adequate, but somehow the total amount never materializes or is diverted during the year. Funds actually available may thus be less than budgeted and later than scheduled.

There is also a tendency in many developing countries to employ very large numbers of people in maintenance projects. The problem when this policy is followed is that there is a great amount of overstaffing; a large proportion of available funds must go for the payroll, leaving an inadequate budget for the tools, materials, and supplies needed for truly productive work.

Governments must be firmly committed to the timely allocation of the funds approved in the budget. If available funds will be less than the amount requested, the proposed work plan and staffing complement must be adjusted accordingly.

Developing countries must first realize that adequate funds for road maintenance are necessary, and then provide a budgeting process that will realistically define the monetary requirements. Better scheduling, control of work, and improved utilization of resources may reduce the amounts originally thought to be necessary. Finally, committed funds must actually be provided, and at the programmed times.

PERSONNEL TRAINING

The experience of most developing countries in road maintenance is quite limited. There is need for training programs in four areas:

1. *Operator Training* — directed to operators of maintenance equipment so that they may effectively use the equipment.
2. *Mechanic Training* — directed to equipment workshop personnel so that they may properly service and repair equipment to minimize down-time and to extend service life.
3. *Work Methods Training* — directed to field supervisors so that they may know and utilize the most effective procedures for maintenance operations.
4. *Management Training* — directed to engineers and officials in the field and headquarters offices so that they may effectively carry out the functions of planning, budgeting, scheduling, and controlling of maintenance programs.

To give it sufficient continuity, status, and weight in broader policymaking for the highway department, the whole function of training or staff development for all levels from senior engineers and managers to patrolmen and drivers needs to be institutionalized. Training efforts have too often been seen as one-shot affairs, without allowance for the fact that 10 percent or more of the staff may need to be replaced each year due to retirements and losses to the private sector, and that remaining staff will need refresher courses. Many developing countries have set up training sections within their highway departments.

MANAGEMENT PRACTICES

Perhaps the most serious problem confronting many developing countries is the lack of any systematic approach to management of highway programs, particularly maintenance operations. The objectives, policies, and procedures for carrying out maintenance programs are not clearly spelled out. Government officials who must review and approve budget requests for highway maintenance operations have little basis for evaluating requests except by comparisons with previous years' expenditures. Proposed expenditures for payroll, equipment, and capital expenditures can be understood, but they give few clues as to what maintenance goals are required, or the level of traffic service that will be provided. When the approved funding turns out to be less than the amount requested, the highway agency has difficulty identifying what the consequences might be in terms of reduced services.

An equally serious problem is the lack of communication between highway agency officials responsible for planning maintenance programs and field supervisors responsible for scheduling and directing the work. Too often, decisions on day-to-day work performance are made solely by the field supervisor, and the end result bears little resemblance to the program of accomplishments conceived by highway agency officials.

The answer to these problems is to develop, adopt, and follow a system of management practices which

1. clearly sets forth the basic road maintenance objectives of the agency, along with the policies, procedures, and the organizational relationships and responsibilities for accomplishing those objectives;
2. defines policies on maintenance work methods as to whether mechanized or labor-intensive practices are used;
3. defines annual programs of specific maintenance work based on the needs of the desired levels of traffic service;
4. identifies the resources needed to accomplish the proposed work program;
5. appropriately allocates resources among the field work force units according to their individual needs;
6. clearly communicates to each field unit the expected accomplishments along with guidance for scheduling and control of work performance;
7. requires that field units be accountable for their progress, accomplishments, and the effectiveness of their operations.

Adopting a systematic approach to maintenance management is a first essential step toward assuring that maintenance programs can be carried out effectively. Chapter IV outlines such a system and presents examples of practical application. Additional guidance in management practices can be found in a recently developed "Highway Design and Maintenance Standards Model," prepared by the World Bank, the Transport and Road Research Laboratory, and Massachusetts Institute of Technology. The HDM Model is a computer program that can be adapted to maintenance budgeting and management. Data generated by the model describe annual maintenance expenditures and an estimate of what average road surface conditions can be expected from various expenditure levels. Currently the HDM Model is in use in several developing countries and shows promise of being a valuable management tool.

CHAPTER II

Typical Maintenance Functions

This chapter will briefly describe and summarize the typical maintenance functions normally required for unpaved roads. The purpose is to establish a common base for understanding the terminology used and to present the general approach for planning, scheduling, and performing the work.

Most highway agencies, even in developing countries, have responsibilities for maintaining some bituminous and concrete paved roads. However, the road system in developing countries usually is largely unpaved. So this discussion is limited to the maintenance of unpaved surfaces and the related drainage and roadside work.

MAINTENANCE TERMINOLOGY

Throughout the years maintenance engineers have developed and generally accepted some terminology for various maintenance operations. Because these terms will be used in this synthesis, the following definitions are set forth for mutual understanding.

1. *Routine maintenance* — those work items regularly performed by maintenance crews throughout the year. Functions such as blading and smoothing the surface, patching potholes, cleaning drainage structures, and cutting vegetation are considered routine maintenance. Scheduling and performance of the work normally are responsibilities of the first-line supervisor of the crews within the overall plan and budget.
2. *Periodic maintenance* — more extensive maintenance operations that are required only every several years. Resurfacing with gravel to replace lost material is an example of periodic maintenance. Because this usually is an expensive operation, authority for planning and scheduling the work usually rests with someone higher than the first-line supervisors. Emergency repairs as a result of floods or slides are types of unplanned periodic maintenance.
3. *Rehabilitation and betterment* — are not really maintenance functions but are included here because the work usually is performed by the same crews responsible for maintenance. The work involves major restoration of roads and minor construction projects for improvement of facilities and normally is programmed by district or headquarters authority.

In setting up a system for planning and reporting maintenance work, the individual functions are grouped in several general categories of work such as:

1. surface maintenance,
2. drainage maintenance,
3. roadside maintenance,
4. bridge maintenance,
5. traffic services,
6. rehabilitation and betterment, and
7. equipment servicing and repair.

To facilitate reporting and record keeping, some type of numbering system usually is established to identify each of the individual maintenance functions. Those functions applicable to non-paved roads are described generally in the following sections. More detailed descriptions of the work methods and procedures can be found in Chapter VI.

SURFACE MAINTENANCE

Unpaved road surfaces commonly require three maintenance functions, each for a different purpose.

1. *Blading and shaping* — are required occasionally to provide a smooth riding surface by correcting transverse corrugations and longitudinal rutting. Preferably, this work is performed with a motor grader, but the smoothing can be accomplished with home-made drags or even by hand tools. The frequency for scheduling blading or dragging depends on (1) the characteristic of the surfacing material, (2) traffic volumes, (3) weather, and (4) the degree of smoothness considered acceptable by the agency for the particular classes of roads. Some low-volume roads may be bladed only once or twice a year, while other roads may require much more frequent smoothing.
2. *Patching with gravel* — involves repair of isolated trouble spots such as potholes, soft spots, surface erosion, shoulders that have slumped, or other locations where surface material nas been lost. Ordinarily a truck is required to transport the gravel, but the placement and smoothing of the patches are done with hand tools. If acceptable material is available near the roadside, wheelbarrows may be used and trucks are not required. This is a routine function performed regularly as trouble spots are observed.
3. *Resurfacing with gravel* — is scheduled for relatively long road sections to replace lost gravel when the need is more extensive than can be corrected with patching. Over a period of time, considerable material is lost as dust during dry seasons or eroded away during wet seasons. Resurfacing is a periodic function usually required about every three to five years — more often in the case of larger traffic volumes and poor surface materials, less frequent with low-volume roads and better materials.

DRAINAGE MAINTENANCE

Water is perhaps the most serious problem for road maintenance, and particularly for unpaved roads. There are several maintenance functions for the purpose of assuring that water continues to drain away from or through the roadway area as originally planned or found to be necessary over a period of time.

Cleaning and repairing culverts are routine functions performed regularly each year. Sediment and debris often collect in pipe culverts and small box culverts causing the flow to be reduced or maybe even stopped completely. During heavy rainfall, sections of the road can be washed away by water which overflows undersize culverts or those blocked by debris. Culvert cleaning is performed mostly with hand tools.

Cleaning of ditches should be performed at regular intervals to remove debris and plant growth so that surface water continues to flow unobstructed. This applies to roadside ditches parallel to the roadway, to inlet and outlet ditches at culvert ends, and at locations where water drains away from the roadway area. Usually ditches are cleaned with hand tools. Motor graders, bulldozers, or other special equipment may be used when long sections of ditches need cleaning and/or reshaping.

ROADSIDE MAINTENANCE

The roadside is considered that area between the shoulder of the road and the right-of-way line. Some maintenance work in this area is for appearance, some for safety, some for road approaches, and some for protection of the roadway.

Cutting of grass is a maintenance function of some highway agencies, mostly for the sake of appearance on the more important roads and in developed areas. Mowing machines can be used, but in developing countries the work is usually performed with hand tools.

Cutting of brush and trees is required as a safety precaution to make sure that motorists have adequate sight distance, that road signs are not obscured, and that branches do not strike vehicles. This is a hand operation and is seldom needed more than once a year.

Erosion control work can be either corrective or preventive maintenance. Roadway slopes and ditches often are subject to severe erosion as a result of heavy rainfall. Eroded spots must be repaired, and steps should be taken to try to prevent the erosion from occuring again at that location.

Litter pickup is scheduled occasionally for appearance, principally near developed areas. However, maintenance personnel must continually watch for and remove dead animals or any debris on the roadway which may be hazardous to traffic.

Bridge Maintenance. Some type of regular periodic bridge inspection program should be established to identify deterioration and needed repairs. Typical bridge maintenance operations include repair or replacement of decks, rails, and structural members, as well as maintenance and repair of stream channels and periodic painting of steel or timber bridges.

TRAFFIC SERVICES MAINTENANCE

In most highway agencies, traffic services include the maintenance and repair of traffic signs, signals, and pavement markings. In the case of rural unpaved roads the concern is principally with sign maintenance.

Sign maintenance involves the repair or replacement of damaged traffic signs and supporting posts. New sign faces may be purchased or manufactured by the agency. Appropriate signs in good condition are essential to the safety and convenience of motorists on principal roads with relatively large traffic volumes. They are desirable but less important for low-volume roads in rural areas.

EQUIPMENT SERVICING

Maintenance equipment requires regular servicing operations, some on a daily basis, to assure effective operation and service life. Maintenance is performed both by full-time servicemen and by the assigned equipment operators. To provide for proper record keeping, an equipment servicing function usually is provided to account for the time of maintenance personnel.

REHABILITATION AND BETTERMENT

Major rehabilitation and betterment work usually is planned and scheduled on a project-by-project basis. In order to be able to evaluate the adequacy and effectiveness of the regular maintenance program, all charges for labor, equipment, and materials allocated for rehabilitation and betterment projects by highway agency forces should be clearly reported and summarized separately from maintenance work.

CHAPTER III

Organizational Framework

When discussing organization, most people think in terms of organization charts showing individual units of the organization, lines of authority, and staff positions to be filled. Such charts provide a good visual overview of the organization and a general idea of the internal relationships. But this is only part of the picture. There is a very essential need to clearly define basic objectives, policies, and the levels of authorities and responsibilities. These policy decisions can have a significant effect on how the organizational structure might best be established.

For example, a small compact nation may elect to retain much of the direction and control of operations at the headquarters level. For a widely dispersed road system involving large areas or groups of islands, it usually is more desirable to have a decentralized organization with more delegation of authority and responsibility to field units.

Wide variations in organization for maintenance among highway agencies, even in highly developed countries, indicate that there is no single best organizational framework. Each highway agency, particularly those in developing countries, should review existing conditions, evaluate alternative practices, and formulate basic policies and procedures as guides for establishing the organization.

A typical organization for maintenance usually includes

1. some type of headquarters unit;
2. regional or district levels, and possibly sub-district units;
3. field workforce units; and
4. units responsible for servicing, repair, and management of equipment.

A clear understanding of the relationships among these units is essential to assure effective maintenance operations. Some current practices and criteria are discussed in the following sections.

GENERAL ORGANIZATION

The major functional areas of highway agency operations include planning, design, construction, maintenance, equipment, materials testing, and administration. In this synthesis, discussions will center around three of these functions—construction, maintenance, and equipment—and the ways in which highway agencies can best organize to carry out these functions.

Several factors influence the manner of organization, specifically the scope of work undertaken by the field forces, the responsibilities of the district offices, and the lines of authority between headquarters units and field offices.

Decentralized Operations

In most developed countries and some more advanced developing countries, a considerable amount of authority and responsibility is delegated to district engineers. The district level sometimes has direct responsibilities for

1. supervision and inspection of projects under construction by contractors,
2. direction of construction by force account work,
3. all maintenance operations,
4. field surveys,
5. some design work,
6. some materials testing,
7. equipment workshops,
8. right-of-way acquisition, and
9. administration.

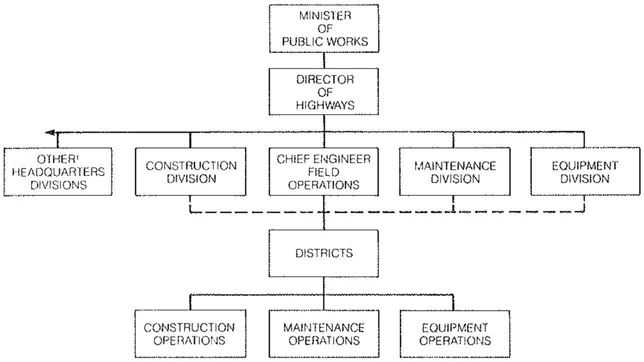
In this capacity, the district offices are in effect small highway departments representing the government in nearly all highway matters within the geographical area. As such, they cannot very well be supervised by any single functional unit at the headquarters level. Commonly, the lines of authority and accountability are to a headquarters chief engineer for field operations. The other headquarters functional divisions principally provide staff guidance and assistance to the field units through the chief engineer. In actual practice, the functional divisions frequently work directly with the district offices, with the blessing of the chief engineer. But the basic line of authority remains between the chief engineer and the districts. This type of arrangement is illustrated in Figure 1. (The illustration shows only the principal functions of construction, maintenance, and equipment.)

Maintenance-Oriented Operations

Organization may be somewhat different in some of the less developed countries. Contract construction projects are not common, except for major improvement work undertaken with foreign funding. The construction, inspection, and supervision for those projects usually are the responsibility of consultants or the construction division at the headquarters level. District offices seldom are involved to any great extent.

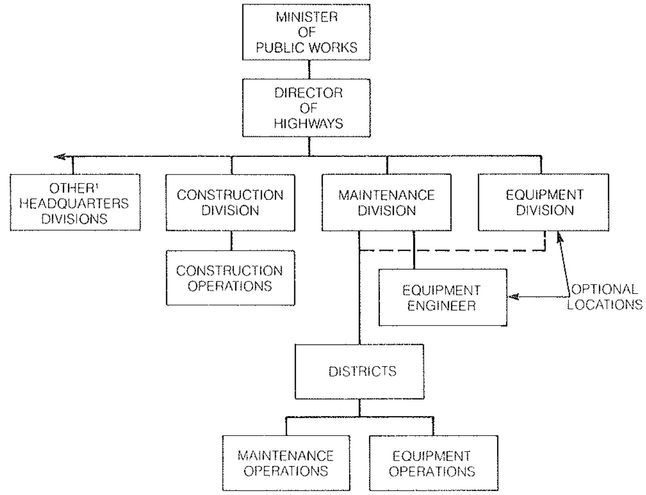
This situation leaves the field units concerned principally with maintenance operations and possibly some minor construction by force account work. In this capacity, the district offices can be under the immediate direction of the headquarters maintenance engineer. The headquarters equipment function then can be a separate staff division, working through the maintenance engineer, or it can be an organizational unit within the maintenance office, responsible to the maintenance engineer. This maintenance-oriented organizational arrangement is illustrated in Figure 2. Most developing countries will find that this maintenance-oriented organizational framework best serves their immediate needs. As development continues *normally*, responsibility at the district level will increase and bring about a need for more decentralization.

Figure 1
TYPICAL DECENTRALIZED ORGANIZATION



— — — Staff assistance only
[1]Planning, Administration, Materials Testing, Preconstruction Engineering, etc.

Figure 2
TYPICAL MAINTENANCE-ORIENTED ORGANIZATION



— — — Staff assistance only
[1]Planning, Administration, Materials Testing, Preconstruction Engineering, etc.

HEADQUARTERS ORGANIZATION

Overall planning, direction, and supervision of maintenance programs usually are delegated to a maintenance division of the headquarters organization. In some agencies, the headquarters unit serves as support staff without direct line authority over field units (Figure 1). In those agencies which are principally maintenance-oriented, the maintenance engineer may exercise direct authority over the districts (Figure 2). Seldom are maintenance crews assigned directly to the headquarters units unless there is need for a highly specialized technical crew (such as traffic signal repair) to serve nationwide.

The head of the maintenance unit normally reports directly to the executive officer of the agency or to a principal assistant. The objectives and responsibilities of the unit include

1. development of maintenance policies and procedures for review and approval by top management and for nationwide implementation;
2. development of uniform work performance standards and manuals of instructions for field units;
3. development of annual maintenance work programs and/or review, adjustment, and approval of annual programs prepared and submitted by field units;
4. preparation and coordination of nationwide maintenance budget requests;
5. coordination of the allocation of resources—manpower, equipment, materials and funds—among the major field units (regions or districts) in accordance with the requirements of approved work programs;

6. guiding and assisting field units in effective planning, scheduling, performance, and control of maintenance programs;
7. reviewing field conditions and nationwide levels of maintenance service being provided, with accountability to top management for accomplishment of approved work programs; and
8. providing effective training for field personnel.

The extent of responsibilities of the headquarters maintenance unit varies with the degree of decentralization employed. But in any case the headquarters unit provides the principal means for promoting uniform and effective maintenance work methods. Headquarters also provides management practices that communicate work program objectives and requires accountability for work accomplishment.

At least four organizational units are needed within the headquarters maintenance division:

1. a planning and budgeting unit,
2. a field operations unit,
3. a traffic services unit, and
4. a training unit.

Equipment control may also be included in the maintenance division, but for the purpose of this synthesis the equipment function will be discussed as a separate headquarters division.

The basic headquarters maintenance organization is illustrated in Figure 3 and discussed in the following sections.

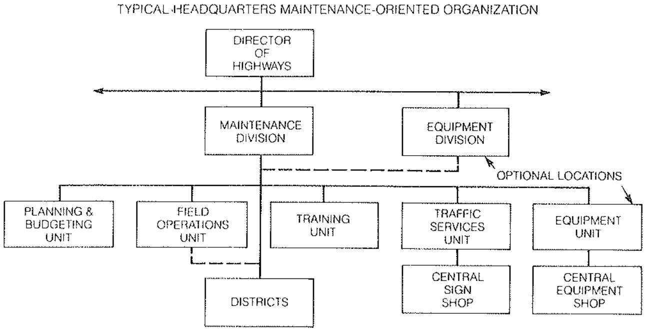
Planning and Budgeting Unit

This unit is responsible for developing and implementing standard procedures for maintenance planning and budgeting as generally described in Chapter IV. The unit works closely with the district offices in identifying maintenance needs and preparing annual work programs for the field units. The unit develops work performance standards and establishes values for planning appropriate uniform levels of maintenance service.

The unit consolidates the various district programs into a national program, prepares cost estimates, and adjusts the work programs as needed to fit available funds. The program is reviewed by top management. Following top management approval, the unit converts the program to the format required by the government for formal budget requests.

Additionally, this unit reviews and evaluates the performance of the various field units by comparing their actual accomplishments with the work program objectives. It provides top management with current information on the progress and effectiveness of the ongoing maintenance work.

Figure 3
TYPICAL HEADQUARTERS MAINTENANCE-ORIENTED ORGANIZATION



---- staff assistance only

Traffic Services Unit

In more developed countries, this unit would be responsible for all traffic signals, signs, and pavement markings. This synthesis is concerned principally with sign installation, maintenance, and repair. In this capacity, the unit would be responsible for

1. establishment of policies, procedures, and manuals for uniform and consistent nationwide signing;
2. supervision of a sign shop for fabrication of traffic signs, or procurement of traffic signs from commercial sources;
3. inspecting the condition and adequacy of existing signing; and
4. directing special sign crews, or guiding and assisting district maintenance crews with regard to traffic signs.

Training Unit

Some agencies establish a central training unit responsible for all training programs throughout the agency. If this is not the case, there should be a training unit within the headquarters maintenance office. Such a unit would be responsible for preparing procedural manuals as well as developing and carrying out training programs on maintenance work methods for field personnel.

DISTRICT ORGANIZATION

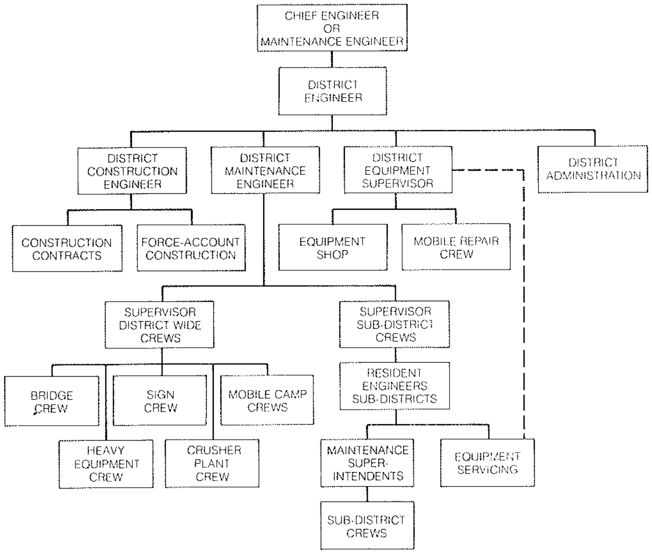
Districts are established to provide a means for more effective management and supervision of maintenance operations. Generally, each district should be responsible for about 500 to 1,000 km of roads. District boundaries frequently are influenced by terrain, rivers, and other geographic features, as well as by the concentration of highways and locations of population centers.

Each district is headed by a district engineer who reports to the headquarters level through the maintenance engineer or the chief engineer of field operations. Field maintenance operations are usually under the direction of a district maintenance engineer. Where large areas are involved, sub-districts may be established within the district, each headed by a resident engineer and with a maintenance supervisor responsible for maintenance within the sub-district area. A typical district organization is shown in Figure 4.

The principal responsibilities at the district level are

1. to coordinate with the headquarters maintenance organization in developing annual maintenance programs of specific work to be accomplished within the region, district, and sub-districts;
2. to define the resources needed (manpower, equipment, and materials) within the area to accomplish the work set forth in the program;
3. to allocate the resources among the sub-districts and field units in accordance with their individual workloads;
4. to assist field units in effective scheduling of work activities in accordance with approved program objectives;
5. to guide, assist, and train field supervisors in proper work methods and procedures;

Figure 4
TYPICAL DISTRICT ORGANIZATION



6. to inspect road conditions and maintenance workmanship, and to direct corrective actions as needed;
7. to implement standard work reporting systems and assure reporting accuracy so that performance can be evaluated by the region and by headquarters on a nationwide basis; and
8. to administer and operate an equipment repair and overhaul facility and provide skilled mechanics to service equipment in the field.

District Headquarters

In addition to the organization needed for administrative responsibilities, each district headquarters usually has separate units for construction, maintenance, and equipment.

1. A *district construction engineer* is in charge of all road and bridge construction, both construction by contract and force account construction. He is assisted by project engineers and construction supervisors. In the case of maintenance-oriented district operations (Figure 2), this function would be carried out by a central headquarters unit rather than a district-level unit.
2. A *district equipment supervisor* would be responsible for the district equipment repair shop, and a mobile equipment repair crew. He would guide and direct sub-district equipment servicing facilities, and would be responsible for assuring effective equipment preventive maintenance programs throughout the district. (This is discussed further in Chapter V.)
3. A *district maintenance engineer* would have responsibility for all road and bridge maintenance work. He is assisted by a maintenance supervisor in charge of all special district crews (bridge crew, sign crew, heavy equipment crew, mobile camp crew, and crusher crew), and a maintenance supervisor in charge of the sub-district maintenance operations.

In most cases, the sub-districts are concerned principally with routine maintenance operations and are headed by a resident engineer or an experienced maintenance supervisor. One or more maintenance superintendents assist the sub-district chief, depending on the number of maintenance crews employed. Each superintendent can supervise three or four crews. Each crew has a foreman. The sub-districts also have a small unit for simple routine servicing of equipment.

WORK FORCE ORGANIZATION

With the exception of an occasional specialized technical crew working out of central headquarters, all maintenance work forces are in one way or another responsible to the district or sub-district offices. The manner in which they are organized and staffed may vary considerably.

District Crews

Some maintenance work requires special knowledge and capabilities, as well as special equipment. Bridge maintenance, sign maintenance, major regraveling, rehabilitation, and crusher plants are examples of this special type of work. Because it is impractical to staff and equip all field units for special work, several specialized crews are commonly established under the district maintenance superintendent to perform the work on a district-wide basis as needed. The work of these crews is scheduled in close coordination with the foremen and supervisors in the sub-districts where the work is performed. It is not uncommon for personnel from local crews to assist the district crews.

For the remainder of the field work forces there are three common ways of organization. Usually, the choice is related to the size of the area and the density or road system.

Maintenance Depots. For small areas and highly compact road systems, maintenance depots or section houses are often placed at strategic locations. These depots provide office space and storage places for equipment, materials, and supplies and usually have some facilities for servicing equipment. All crew members report to the depot each morning for assignments and are transported in groups to the various work sites designated for that day. At the end of the work day, they report back to the depot before going home. Depending on conditions, each depot may be staffed with as few as 10 or 12 persons or as many as 50 persons.

Road Section Crews. When the area is larger and the road system is less dense, it becomes impractical to transport crews long distances between a depot and work sites each day. In this case, road sections ranging from 15 or 20 kilometers up to about 50 kilometers may be established. A maintenance foreman, about 10 to 20 crew members, and appropriate tools and equipment are assigned to each section. The crew is responsible for all routine maintenance. All crew members usually live in close proximity to the road section and report to the foremen each day. The work is mainly labor-oriented with hand tools. There is little mechanization except for basic transport, sometimes limited to bicycles. When maintenance equipment is required for a particular operation, it is scheduled out of a district or sub-district office. Foremen of the road sections are directed and supervised by district maintenance supervisors.

Highway agencies in some developing countries follow the practice of part-time employment of local inhabitants for maintenance work along remote sections of rural roads. The individuals are not regular full-time employees of the agency. They are employed occasionally by the district or sub-district maintenance supervisors for short periods of time to perform specific needed maintenance work on the adjacent road sections. This can be a more economical approach, particularly for those low-volume roads requiring only limited maintenance attention.

Mobile Crews. In remote, very sparsely populated areas, even the road section approach to maintenance organization sometimes is not practical. Some agencies resort to traveling crews which undertake maintenance of long distances of roads in remote locations over a period of several months. The traveling crews usually are reasonably well mechanized and are provided with mobile camp facilities for crew members. Also included are mechanics and facilities for servicing and repair of equipment. Because of the nature of this approach, there may be long periods of time between maintenance work on individual road sections—possibly a year, or even longer. With infrequent attention, road deterioration often is more severe and the level of service is less than adequate during much of the year. When crews do return to a long-neglected road section the work is more extensive, often approaching rehabilitation rather than maintenance. The seriousness of this problem depends on whether the work is on remote sections of principal main highways or on lesser traveled local roads.

The best organization of maintenance work forces in the field is related to the characteristics of the road system and the extent of mechanization adopted by the agency.

EQUIPMENT ORGANIZATION

Regardless of the organizational placement of the equipment function within a highway agency, the following actions and responsibilities are necessary:

1. determination of the types and numbers of equipment needed to carry out the maintenance program most effectively and economically;
2. preparation of specifications and bidding documents, and the acceptance and evaluation of bids for purchase of equipment.
3. management of the equipment fleet, including practices for allocation among field units, record keeping on utilization and costs, and policies on replacement and disposal of obsolete equipment;
4. carrying out a program of equipment servicing and repair to assure a minimum down time and a maximum service life; and
5. assuring an adequate continuing inventory of commonly needed spare parts and supplies.

Many agencies establish equipment organizational units that are entirely separate from the maintenance organization, both at headquarters and at the field levels. The equipment unit is headed principally by a mechanical engineer who has responsibility to manage the equipment fleet so as to serve effectively all equipment users within the agency.

Within most highway agencies, the maintenance organization normally is the largest user of equipment. Consequently, some agencies combine the equipment function with the maintenance organization in order to provide better coordination for carrying out maintenance programs.

Each approach has its own merits. Special expertise is needed in the management of both functions, and coordination is essential. The location of the equipment function within the organization is not so important. What is important is that the policies, procedures, and responsibilities be clearly defined and understood; that the equipment function is responsive to the maintenance program by providing appropriate equipment in good condition where and when it is needed; and that the maintenance function is knowledgeable of and follows criteria for proper operation, servicing, and care of equipment.

Headquarters Equipment Organization

Most highway agencies have an equipment unit within the headquarters organization with responsibilities for

1. procurement of new equipment;
2. establishing operational policies and procedures for management of equipment;
3. directing and supervising a central repair shop that is responsible for major overhaul and repair;
4. coordinating the acquisition, warehousing, and distribution of spare parts and supplies;
5. establishing policies, procedures, and practices for field workshops and the servicing and repair of equipment; and
6. developing manuals of procedures and training for field personnel.

These functions and responsibilities normally can be carried out with three organizational units at the headquarters level:

1. a *central equipment workshop* responsible for all major overhaul and repair of equipment and for central procurement and warehousing of spare parts and supplies to be distributed to the various field workshops;
2. an *equipment management unit* responsible for analyzing equipment needs, procuring equipment, distributing and controlling equipment, and establishing policies for effective operation and care of equipment; and
3. an *equipment training unit* responsible for developing and implementing programs of training for equipment operators, servicemen, and mechanics in order to assure proper operation, maintenance, and repair of equipment.

District Equipment Organization

The field organization for the equipment function consists principally of equipment workshops, warehousing of equipment parts and supplies, and facilities for field servicing of equipment. Major workshop facilities usually are established at regional or district headquarters with smaller workshops or service facilities at selected locations throughout the area. Service trucks are often used for servicing and minor repairs of equipment at remote locations.

In some instances, the headquarters equipment office exercises direct line supervision over the field units. Most often, the field equipment units are responsible to the regional or district engineer, with the headquarters organization serving as support staff.

ORGANIZATIONAL RELATIONSHIPS

Perhaps the most important factor in organizing for maintenance of roads and bridges is that the organizational framework must be responsive to the policies, systems, and procedures established to get the job done most effectively. Decisions on basic policies, procedures, and management practices should be made first. Many people will be involved at different organizational levels, and their responsibilities and relationships need to be clearly set forth. Once this is done, objective decisions can be made on the organizational structure. The chart will almost draw itself.

The next chapter will discuss some of the management practices that can influence decisions on how best to organize for road maintenance.

CHAPTER IV

Management Practices

An effective road maintenance program depends to a large extent on good management practices. Too often, highway agencies provide a maintenance work force, equipment, and materials, then rely on field personnel to allocate these resources and to plan and execute day-to-day maintenance operations. The results generally are not satisfactory, and the levels of service throughout the road system are inconsistent. There also is a tendency to assume that more workers, equipment, and money will improve the levels of maintenance. The reality is, however, that it is a good system of management that can significantly improve maintenance conditions.

Improvement in the efficiency of maintenance operations is an important issue in most developing countries, both because of the opportunity that exists for accomplishing more with available funds, and because finance ministries tend to cut requested budgets on grounds that the funds would not be well spent. Typical major problems are excessive numbers of staff, inadequate staff supervision, low equipment availability and utilization, low productivity compared with nongovernment organizations performing similar functions, diversion of equipment and effort to nonmaintenance work, and periodic running out of funds.

Most of these problems can only be solved over time by staff attrition, introduction of more flexibility in public service personnel policies, training of middle management, setting up better arrangements for assuring a regular flow of spare parts, limiting interference by politicians and local dignitaries, and by finding alternative ways of meeting local needs for modern equipment for local projects.

Some of the more advanced highway agencies have developed complex maintenance management systems that use electronic computers. However, this degree of sophistication is not warranted in most developing countries. All management systems whether computerized or not, should include formal procedures for

1. planning annual work programs with specific work to be accomplished,
2. determining the most effective ways for performing the work,
3. allocating the available resources to execute the program,
4. authorizing and scheduling work in ways that are clearly understood by work forces, and
5. reporting work and evaluating performance.

This chapter will discuss the basic elements of maintenance management practices as they might be appropriate for most developing countries. Examples of practical applications of these procedures will be presented. Experience suggests that management may in fact be helped most by introducing new systems rather cautiously and slowly, except where responding directly to already realized needs. At the earliest stages it may be best not to attempt much regular collection of detailed data for planning purposes (such as quantities and costings, traffic counts and deflection measurements), or even for detailed comparison against plan. Instead, the focus should be wholly on two systems, one largely a matter of training and attitudes, and the other a full-scale management information system that is limited to equipment operation and maintenance.

WORK ACTIVITY DEFINITION

Typical maintenance work activities were discussed in Chapter II. Each agency should establish its own list of individual work activities that will be performed by maintenance forces. Figure 5 shows a listing of typical activities that will be performed on unpaved roads. Each activity should be described in greater detail in a work methods performance standard (Chapter VI). A code number is assigned to each activity for use in planning and reporting of work.

One other important element shown on the activity listing is an established work measurement unit for each activity. The management system will be concerned not only with the planning and control of money, but also with the planning and control of quantities of work accomplished. The work measurement units should be readily identifiable and easy to measure and report. Some will be quite obvious, such as kilometers bladed, or number of culverts cleaned. For others it may be necessary to resort to man-hours as a measure of work effort and accomplishment.

From the standpoint of good management, it is essential that there be clear understanding between the planners and the work forces as to the scope and intent of each maintenance activity and the basis for measuring work quantities. A listing such as Figure 5 could provide a starting point from which refinements would be made as an agency gains experience.

ROAD SYSTEM CLASSIFICATION

The road system in most countries is comprised of routes and road sections that vary widely in characteristics of surface type, condition, and the services they are expected to provide. Thus all roads cannot be treated the same when planning and carrying out maintenance programs. Segments

Figure 5

MAINTENANCE ACTIVITY DEFINITIONS
AND
WORK MEASUREMENT UNITS

Code	Description	Work Unit
	ROADWAY SURFACES	
10	Blading and Shaping of unpaved surfaces with motorgraders, drags, or hand tools to remove corrugations and rutting - without adding material.	Km. Bladed
11	Patching small isolated potholes and soft spots with suitable new material.	Cu. Meters
12	Resurfacing of long continuous sections to replace lost surfacing material.	Cu. Meters
	DRAINAGE	
20	Cleaning and Repairing Culverts with hand tools.	No. of Culverts
21	Hand Cleaning of Ditches with hand tools.	Meters of Ditch
22	Machine Cleaning of Ditches with motor grader or other motorized equipment.	Km. of Ditch
	ROADSIDE	
30	Vegetation Control, cutting of brush, trees and grass with hand tools.	Man-hours
31	Erosion Control, repair and prevention of roadside erosion.	Man-hours
	BRIDGES	
40	Channel Clearing, cleaning the waterway of brush, debris and sediment at bridge sites.	No. of Bridges
41	Bridge Repair, repair of bridge rail, bridge decks and structural elements.	Meters of Bridge
42	Cleaning and Painting, periodic cleaning and painting of steel bridges.	Liters of Paint
	TRAFFIC SERVICES	
50	Sign Maintenance, repair and replacement of damaged signs and sign posts.	No. of Signs
	REHABILITATION AND BETTERMENT	
60	Special Projects, restoration or improvement work on designated road sections -- as well major emergency work such as removing slides and repairing dikes and retaining structures.	Estimated Work Quantities

of the road system must be placed in categories that reflect the variations in realistic maintenance needs. These variations exist even among different kinds of unpaved roads. An unpaved main highway with considerable traffic will require more surface maintenance attention than a lightly traveled road that provides mostly local service. Those roads that are designed and constructed with better materials and to modern standards of alignment, grade, and drainage may require less maintenance than comparable road sections that are inadequately constructed.

The following four classes are suggested as an appropriate breakdown of unpaved roads for the purpose of maintenance planning:

Class I — Principal main highways designed and constructed to modern standards.

Class II — Principal main highways with substandard alignment, grades, drainage, or surface material causing special maintenance problems.

Class III — Secondary roads of lesser importance, constructed to standards adequate for low traffic volumes. Maintenance for all-weather travel is justified.

Class IV — Tertiary or local roads, usually of a primitive nature, that carry little traffic and have few maintenance needs. It may not be necessary to keep these roads open for all-weather travel.

There are no fixed criteria relating traffic volumes to particular road classes. Individual agencies may wish to establish their own relationships. Primary highways normally will exceed 200 ADT. Traffic volumes on Class IV roads usually will be less than about 20 ADT. Designated road classes should be color coded on a map of the road system.

ROADWAY INVENTORY

In order to establish a basis for planning a maintenance program, there is need to conduct an inventory of the roads to define clearly the scope and characteristics of the system to be maintained. If the system is not legally defined it should be established by official policy statements of the agency so that there is no question about the extent of maintenance responsibilities.

Using the system map that identifies the road classes described in the preceding paragraph, the system is divided into individual road sections, each having reasonably uniform characteristics of surface type, width, condition, and traffic volume. These sections may range in length from a few kilometers to as long as 50 kilometers or more; the characteristics should be generally the same throughout. Road sections should also be divided at the boundary lines of each district or other field management unit so that the responsibilities of each field unit can be identified.

A numbering system should be used to identify individual road sections. The following suggested approach involves a combination of route numbers and kilometer numbers.

1. *Route numbers* are assigned to long continuous segments of the system that connect major cities or other control points. All routes that are for east-west travel are given an even number. North-south routes are assigned an odd number.
2. *Kilometer numbers* show the distance from the beginning of the route to the beginning of the particular road section. The beginning point is always at the west end for east-west routes and at the south end for north-south routes.

This system provides easy identification of road sections. For example, section 12-60.5 would begin at a point 60.5 km east of the west end of route 12, and section 5-103.2 would begin 103.2 km north of the south end of route 5.

After the road sections have been established, each section should be inventoried in the field by an engineer or experienced maintenance supervisor, and the information recorded on a field inventory sheet. Standard forms similar to that shown in Figure 6 should be provided for recording the information.

The information compiled on the field sheets should then be summarized for each management unit, first by sub-districts, then by districts, and then nationwide. An example summary sheet is shown in Figure 7. Such summary sheets, updated annually, provide for evaluation of the road system as well as a realistic basis for planning and estimating maintenance programs.

LEVEL-OF-SERVICE STANDARDS

Planning for maintenance work requires some preliminary determination of the desired levels of service. Usually the levels of service are related to the several road classifications because a level of service acceptable for a remote road with low traffic volume would be unacceptable for a principal highway with heavy traffic. The standard for the main highways would be uneconomical for roads of lower classification.

Figure 6

ROADWAY INVENTORY FIELD SHEET

District ________________ Prepared by ________________
Sub-district ________________ Date ________________

Road Section No ________________ Road Class ________________
From ________________ To ________________

Section Length ________________ km | Average Roadway Width ________________ meters

Surface Type
☐ P C Concrete
☐ Bitum Concrete
☐ Bitum Surf Treat
☐ Gravel
☐ Soil

Surface Condition
☐ Very Good
☐ Good
☐ Fair
☐ Poor
☐ Very Poor

Roadside Ditches ________________ km | Other Ditches ________________ meters

No of Culverts ________

Drainage Condition
☐ Very Good
☐ Good
☐ Fair
☐ Poor
☐ Very Poor

Vegetation Control Condition
☐ None
☐ Light
☐ Medium
☐ Dense

No of Bridges
Steel ________________
Concrete ________________
Wood ________________

Length of Bridges
Steel ________ meters
Concrete ________ meters
Wood ________ meters

No of Signs

Special Maintenance and or Rehabilitation Needs ________________

Some roads must be all-weather roads; others might be temporarily closed during periods of heavy rain, or even seasonally.

Level-of-service standards can be measured according to the frequency of maintenance required. For example, a primary highway may require blading and shaping at least once a month. Less frequent intervals may be adequate for a secondary road, and once or twice a year may provide adequate service for a lightly traveled local road. Similar variations in the frequency of maintenance operations may be appropriate for

Figure 7

ROADWAY INVENTORY SUMMARY SHEET

District .... Prepared by ....
Sub-District .... Date ....

Road Class	Class 1	Class 2	Class 3	Class 4	Total
Length (km)					
Surface Type (km) P C Concrete Bitum Concrete Bitum Surf Treat Gravel Soil					
Roadside Ditches (km)					
Other Ditches (meters)					
No of Culverts					
Drainage Condition (km) Very Good Good Fair Poor Very Poor					
Vegetation (km) None Light Medium Dense					
No of Bridges Steel Concrete Wood					
Length of Bridges (meters) Steel Concrete Wood					
No of Signs					

Figure 8

ILLUSTRATIVE LEVEL-OF-SERVICE STANDARDS

Maintenance Activity	Performance Criteria	ROAD CLASS Class 1	Class 2	Class 3	Class 4
Blading and Shaping	Frequency	1 month	2 months	6 months	12 months
Patching	Cm/km/year	10	6	4	
Resurfacing	Frequency	4 year	5 year	6 year	8 year
Clean & Repair Culverts	Frequency	6 months	1 year	1 year	2 year
Ditch Cleaning & Shaping	Frequency	1 year	1 year	2 year	2 year
Vegetation Control	Frequency	4 months	6 months	1 year	2 year
Erosion Repair & Control	Man days/km/yr	60	40	20	10
Litter Pickup	Frequency	6 months	1 year		

NOTE: The values in the table reflect judgments of some highway agencies as to appropriate levels of service, but should not be considered as standards for general application. Variations in climate, terrain, soils, and other factors may indicate the need for different values. Decisions should be made by each agency based on engineering judgment and experience.

drainage work, ditch cleaning, regraveling, and other functions. Examples of typical level-of-service standards for several maintenance activities are shown in Figure 8. These examples should be considered only as general guides. They represent reasonable objectives for average conditions. The more advanced developing countries may realistically set higher service standards. Less developed countries with fewer resources may need to accept lower levels of service.

Decisions on level of service are very important because they will greatly affect the requirements for manpower, equipment, materials, and funding, which must be balanced against available amounts. Field supervisors must be aware of the intended level of service in their day-to-day scheduling of work.

WORK PERFORMANCE STANDARDS

Usually there is a best way to perform each of the various maintenance operations, i.e., a best way from both the standpoint of the quality of workmanship and the economical utilization of manpower and equipment. There are also reasonable standards for expected work accomplishment. A highway agency should establish work performance standards for each maintenance activity, and make certain that field supervisors meet these standards.

Standards, as they are established, should be documented in a maintenance manual and incorporated in training programs. The standards should include

1. the most effective crew size for each maintenance function,
2. the tools and equipment to be provided,
3. materials needed,
4. detailed work methods and procedures, and
5. an estimate of the average daily result expected when following the standard.

Figure 9 shows an illustrative maintenance performance standard for the activity of blading and shaping with a motorgrader. Similar standards for other activities should be documented in this manner. Chapter VI discusses alternative work methods and procedures which might be incorporated in performance standards, based on existing conditions and the operating policies adopted by an agency.

Besides providing guidance for field forces, the standards also provide a realistic basis for estimating resource requirements for the annual work programs and budgets. Standards may vary among different agencies, depending on adopted practices for equipment utilization and the framework for organization. But the objectives remain the same, i.e., to assure a uniform and consistent quality of workmanship in the most economical and effective manner, as appropriate for the particular agency.

Figure 9

MAINTENANCE PERFORMANCE STANDARD
Activity Blading and Shaping
Activity Code 10

Description and Purpose:
Periodic shaping and smoothing of unpaved road surfaces with a motor grader to (1) remove corrugations, (2) correct rutting and other surface irregularities, (3) redistribute loose surfacing material from shoulders, and (4) to restore proper roadway crown to provide drainage of surface water.
Performance Criteria:
To be scheduled and performed at time intervals according to the level-of-service standards established for the particular road class and location. Should be scheduled shortly after rainy period when there is a small amount of natural moisture in the surface. Avoid scheduling the work under extremely wet or extremely dry conditions.
Crew, Equipment and Material:
Crew: 1 Equipment Operator, 2 Laborers, 2 Flagmen — Equipment: 1 Motor Grader, Shovels, Rakes — Materials: None
Work Methods:
1. Place signs and safety devices. 2. Make pass with motor grader pulling loose material from shoulder, cutting high spots and placing windrow at center of roadway. 3. Make second pass with motor grader in opposite direction in the same manner, depositing material in windrow at center. 4. Adjust blade for proper crown slope of 3% and spread material evenly toward each shoulder. 5. Check crown slope with slope board and make additional passes to assure correct crown. 6. Remove all rocks and oversize material form the surface, and rake smooth where necessary. 7. Remove signs and safety devices.
Work Measurement Unit:
Km bladed and shaped
Average Productivity:
6 Km per day

ANNUAL WORK PROGRAMS

A basic part of maintenance management practice is the development of an annual work program that identifies the specific kinds of work to be performed, the amount of each kind of work, and the manpower, equipment, and materials needed to perform the work. Such programs are developed for individual field management units (districts, sub-districts, etc.) and consolidated for a nationwide program. The annual work program is developed from four sources of information:

1. the current *roadway inventory*, which identifies the length of the road system responsibilities by road classes, and the characteristics and condition of individual road sections;
2. the adopted *level-of-service standards*, which identify the estimated annual quantity or frequency of work needed for appropriate maintenance conditions;
3. the *work performance standards*, which provide a basis for estimating productivity and resource requirements; and
4. *periodic field inspections* to identify needed special rehabilitation and betterment work.

After all the information is assembled, it may be necessary to adjust some of the preliminary estimates to fit the available resources.

Figure 10 shows a typical annual maintenance program documentation for several selected work activities. In the example, the *blading and shaping* requirements were computed from the field inventory summary sheet (Figure 7) and the level-of-service standards (Figure 8) in the following manner.

Figure 10

ANNUAL MAINTENANCE WORK PROGRAM

PROGRAM YEAR ________

District ________
Sub-District ________

Activity		Work Unit	Total Annual Units of Work				
Code	Description		Class 1 Roads	Class 2 Roads	Class 3 Roads	Class 4 Roads	All Roads
10	Blading & Shaping	Km Bladed	1 800	1 350	1 050	600	4 800
11	Patching	CM Material	1 500	1,350	1 400	1.200	5 450
12	Resurfacing	CM Material	18 750	16 500	12 300	9 500	57 050
20	Clean & Repair Culverts	No. of Culverts	3 300	1 150	1 050	450	5 950
21	Hand Cleaning Ditches	Meters of Ditch	5 300	5 600	8 400	9 500	28 900
22	Machine Cleaning of Ditches	Km of Ditch	270	190	75	50	585
30	Vegetation Control	Man-days	560	440	275	200	1 475
31	Erosion Control & Repair	Man-days	380	290	230	260	1.160
50	Sign Maintenance	No. of Signs	1 600	850	420	110	2 980

Road Class	Inventory Kilometers		Frequency (per year)		Annual Km. Blading
Class 1	150	×	12	=	1,800
Class 2	225	×	6	=	1,350
Class 3	350	×	3	=	1,050
Class 4	600	×	1	=	600
	1,325				4,800

Using the same information sources, the estimated cubic meters of *patching* for unpaved roads were computed.

Road Class	Inventory Kilometers		CM/Km/yr.		Annual CM Patching
Class 1	150	×	10		1,500
Class 2	225	×	6	=	1,350
Class 3	350	×	4	=	1,400
Class 4	600	×	2	=	1,200
	1,325				5,450

For the activity *clean and repair culverts*, the inventory item of "number of culverts" is used to compute the annual work program.

Road Class	Inventory No. of Culverts		Cleaning Frequency (per year)		Annual No. Cleaned
Class 1	1,650	×	2	=	3,300
Class 2	1,100	×	1	=	1,100
Class 3	1,050	×	1	=	1,050
Class 4	900	×	0.5	=	450
	4,950				5,900

The computation of cubic meters of resurfacing in the program is based on the average resurfacing depth for each road class. This provides values for cubic meters of resurfacing per kilometer. The annual requirements then are based on frequency of resurfacing. Figure 8 shows that one-fourth of all Class 1 roads should be resurfaced each year, while only one-eighth of the Class 4 roads would be resurfaced annually.

Annual work quantities for all other maintenance activities are computed in the same manner, using the appropriate road inventory items, level-of-service standards, and work performance standards.

Any special projects for rehabilitation and betterment work are clearly defined individually, along with estimates of the resource requirements for the work.

RESOURCE REQUIREMENTS

The work program defines the kinds and amounts of work to be performed during the year. The performance standard provides a way of determining what resources are needed. For example, the work program in Figure 10 shows that there should be about 4,800 km of blading unpaved surfaces during the year. The performance standard (Figure 9) shows that a standard crew should average about 6 km per day when blading and shaping. This means about 800 crew days of blading and shaping will be required.

The standard crew consists of five men, one motorgrader, and miscellaneous hand tools. No materials are required for this operation. The resources needed for the 800 crew days amount to 4,000 man days and 800 motor grader days.

In the same way, the resource requirements are estimated for all other maintenance activities in the following sequence:

1. *annual quantities* of work units are identified from the work program;
2. *annual crew day requirements* are computed from estimated productivity rates;
3. *manpower and equipment requirements* are determined from standard staffing patterns and equipment assignments; and
4. *materials requirements* (when applicable) are derived from the work program and performance standards.

Figure 11 shows a format suitable for summarizing the resource requirements. These summaries should be prepared for each sub-district, and should serve as a basis for staffing patterns and for allocation of equipment and materials. Totals of the sheets will give annual man days by employee classification, equipment days by type of equipment, and quantities of each kind of material.

Except for surface patching or renewal, maintenance operations on unpaved roads require few materials. The needs are limited principally to items such as replacement pipe culverts; timber and hardware for bridge repairs; paint, cement, and sign materials. Annual quantities of these items can be estimated on the basis of experience, taking into account any unusual repairs that might be anticipated during the coming year.

PERFORMANCE BUDGETING

Officials responsible for reviewing and approving budget requests usually are not very familiar with the details of road maintenance operations. They learn little from traditional budget requests that simply set forth estimated requirements for labor, equipment, and materials. Performance budgeting is a simple direct way for overcoming this lack in communication.

Performance budgeting relates financial needs to specific work accomplishment as set forth in the annual work program. Objective evaluations thus can be made of the consequences when budget reductions are necessary. It is not just a matter of cutting the payroll or broadly reducing expenditures. It is a question of which maintenance work activities will be reduced or eliminated, and the effect this will have on the level of service.

One continuing problem is the pressure to add routes to the road system, or to increase the level of maintenance service for some of the lower class routes. Performance budgeting will permit identification of the budgetary increases needed for these additional services.

Most governments have prescribed formats and procedures for budgetary submissions by all government agencies. It is unlikely that a highway agency can depart from these formats. But a performance-based budget can be prepared and submitted as substantiation of the formal budget request.

Figure 12 shows a suitable format for a maintenance performance budget. It defines the work to be done (work units for each activity); the labor requirements (man-days for each activity); and the breakdown of costs in terms of labor, equipment, materials, and contractual services for each activity. All regular maintenance activities are identified in this manner. Any rehabilitation or betterment work is identified on the form as a special project, with the work to be accomplished, the locations, and the estimated costs clearly identified.

Performance budgeting need not be a complex task. It is necessary only to maintain current cost data for labor materials and equipment and to apply these costs to the resource needs identified in the annual work program. A more detailed discussion of equipment costing, including the use of equipment rental rates, is presented in Chapter VI.

WORK AUTHORIZATION AND SCHEDULING

After the work program and budget are approved, the work plan must be communicated to the local area maintenance supervisors so they know what work they are authorized to perform, when it should be done, and what resources have been budgeted. Without this communication, it is unlikely that actual work performance will be in accordance with approved objectives.

In the case of special rehabilitation and betterment work, there is no particular problem because the projects can be quite clearly defined in terms of type of work, location of work, and time schedule for completion. But communicating the routine maintenance program and schedule is a little more difficult. One approach is to provide the supervisor of each maintenance area with a copy of the approved program. This tells him the amount of each maintenance activity he should perform during the year, but it does not tell him where or when.

Figure 11

ANNUAL MAINTENANCE PROGRAM RESOURCE REQUIREMENTS
PROGRAM YEAR ________

District ________
Sub District ________

Activity		Work Units	Crew Days	Man Days		Equipment Days		Materials	
Code	Description			Class	No	Class	No	Description	Quantity
10	Blading and Shaping	4 800 Km	800	Equip. Opr Laborer	800 3 200	Motor Gr	800		

Figure 12

MAINTENANCE PROGRAM PERFORMANCE BUDGET
PROGRAM YEAR ________

District ________
Sub-District ________

Activity		Work Program		Costs by Object of Expenditure				Total Budget ($)
Code	Description	Work Units	Man Days	Labor ($)	Equipment ($)	Materials ($)	Contractual Services ($)	

Figure 13

BIWEEKLY MAINTENANCE SCHEDULE

District Sub district
Period
Approved

Work Activity: Code	Work Activity: Description and Location	Est Crew Days	Crew Leader	Man-Day Assignments: Mon	Tues	Wed	Thur	Fri	Mon	Tues	Wed	Thur	Fri
10	Blading & Shaping Route #20	4	R. Jones	5	5	5	5						
10	Bleding & Shaping Route #7	6	R. Jones					5	5	5	5	5	5
11	Patching Route #12	5	P. Smith	6	6	6	6	6					
20	Cleaning Culverts Route #12	5	P. Smith						6	6	6	6	6
31	Erosion Repair Clark River Crossing	10	J. Snyder	9	9	9	9	9	9	9	9	9	9
50	Sign Maintenance Route #4	7	M. Peters	4	4	4	4	4	4	4			
50	Sign Maintenance Route #20	3	M. Peters								4	4	4

Figure 14

ILLUSTRATIVE CREW-DAY CARD

Crew Schedule Card — Crew Size — Activity Code

Road Class ______ Sub-District ______

Activity: ______
Location: ______
Foreman: ______ Date: ______

Labor		Equipment	
Hrs.	Employee	Hrs.	Equip. Unit.

Material

Description	Unit	Amount

Accomplishment ______ Quantity ______ Work Unit

It is difficult for a first-line supervisor to schedule day-to-day operation on the basis of a total annual program.

In some agencies, the planners at the headquarters or district level divide the annual program into smaller time periods, either quarterly or monthly. When preparing these smaller increments of the annual program, consideration must be given to the seasonal requirements of particular maintenance activities. For example, a large portion of the surface patching should be scheduled during and immediately after the wet seasons, and much of the culvert cleaning should be scheduled prior to them. It is also necessary to balance the workload throughout the time periods so that the man-day and equipment-day requirements for the work remain fairly constant.

These short-range programs will help area maintenance superintendents to plan and schedule the work. But because the superintendents usually direct several individual foremen and their crews, there is also a need for individual scheduling of each crew. One of the most effective practices is to arrange regular meetings between the superintendent and his foremen to develop detailed weekly or bi-weekly schedules of specific assignments for each crew and for specific time assignments of any equipment that might be shared among several crews. Figure 13 shows a format suitable for planning and documenting a biweekly schedule for individual crews.

Another approach that is used by some agencies for authorizing and scheduling maintenance work uses a type of work order commonly called a crew-day card. An illustrative crew-day card is shown in Figure 14. Each area superintendent is provided a number of these cards for each activity according to the numbers of crew days specified in the program for the particular activity. They are issued to individual foremen on a scheduled basis as both authorization and direction to perform specific work during the time period. A special advantage of this approach is that the crew-day cards can also be used for reporting work as described in the next section.

WORK REPORTING AND CONTROL

There are two reasons why reporting work is a necessary part of carrying out maintenance programs:

1. *accounting information* is needed for payrolls, accounting for expenditures for materials and supplies, and for cost accounting as related to maintenance programs; and
2. *management information* is needed to review work performance, evaluate progress toward program objectives, to guide corrective action needed to improve work performance, and for advance planning.

Some agencies satisfy both requirements in a single reporting system, while others have separate reporting for accounting and for management information. From this standpoint, simple reporting systems should be developed and implemented to fulfill the following basic criteria:

1. daily or weekly work reporting of each crew should identify the kind of work performed, the work location, the resources used, and the actual accomplishments in terms of work measurement units; and
2. summaries of reported work should be prepared at monthly intervals in ways that compare actual accomplishments with the planned work program of each field unit, and to evaluate work performance in terms of productivity and performance standards.

The type of crew-day card used for work authorization and scheduling (Figure 14) also serves as a good work reporting document. If crew-day cards are not used by an agency, a separate reporting form is needed. Figure 15 shows an illustrative weekly maintenance report. The form would be prepared by the crew foreman and submitted at the end of each week. A separate sheet would be needed for each different work activity performed during the week. Under some conditions clerks would be provided to assist the foremen in preparing reports.

Figure 16 illustrates a typical monthly report which summarizes the performance of a district for a 9-month period from January through September. The example shows an analysis of the activity of blading and shaping. (In actual practice, all reported activities would be listed.) The information is recorded for individual sub-districts, permitting comparisons among the sub-districts as well as with the total district. Similar nationwide summaries would be prepared, comparing all the districts.

Figure 15

WEEKLY MAINTENANCE REPORT

Period from ________ to ________

District ____________ Sub-District ____________

Activity Code ________ Activity Description ________________

Work Location ____________________

Labor	Hours							
Employee	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Total
Total Hours								

Equipment	Equipment Hours							
	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	Total

Materials		Quantity							
Description	Unit	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Total

Accomplishment		Quantity							
Description	Unit	Sun	Mon	Tues	Wed	Thur	Fri	Sat	Total

Foreman ________________

Figure 16

ILLUSTRATIVE SUMMARY PERFORMANCE REPORT

MONTHLY PERFORMANCE REPORT — District — Period from — to

Activity		Work Quantities				Crew Days To Date	Productivity		
Code	Description	Work Measure	Accomplished To Date	Annual Program	Percent Accomplished		Units Actual	Crew Day Std	%
10	Blading & Shaping	Km Bladed							
	Sub-Dist 1		1,059	1 400	75%	233	4.5	6.0	75%
	Sub-Dist 2		540	900	60%	80	6 7	6 0	112%
	Sub-Dist 3		1 400	1 650	85%	180	7 8	6 0	130%
	Sub-Dist 4		380	850	45%	105	3 6	6 0	60%
	District Total		3 370	4 800	70%	598	5 6	6 .0	93%

Two important evaluations can be made from these summaries:

1. the current progress of each field unit toward accomplishing the program objectives is measured as a percentage of the annual program; and
2. the efficiency of operations as measured by productivity. In the example, productivity is the actual kilometers bladed per crew day of work.

A principal purpose of the performance reports is to provide managers with timely information so that problem areas can be pinpointed and corrective actions can be taken. Typical actions might include guiding and assisting supervisors for better work scheduling, or training of field work forces in standard work methods and improved productivity.

MANUALS AND TRAINING

One of the problems common in most highway agencies in developing countries is that systems and procedures for managing maintenance programs have not been formally established. Or if they have been established, the practices are not consistently interpreted and followed. There is a need for uniform understanding among all levels of the agency, at headquarters and in the field, as to how the maintenance program is to be formulated and carried out.

The types of information that should be documented in official policy statements include

1. the basic organizational structure for maintenance, the authorities and responsibilities at each level, and the relationships with other organizational units within the agency;
2. policies and responsibilities for preparing annual maintenance programs including detailed procedures for roadway inventories, level-of-service standards, and work performance standards;
3. policies and responsibilities for preparing performance-based budgets and for allocating resources among field operating units;
4. policies on equipment utilization and management including equipment repair shops and spare parts; and
5. policies on construction and betterment work by agency work forces and by contractors.

The policies, systems, and procedures should be carefully developed with the involvement and participation of the various organizational levels that will be called upon to carry out the programs. This will promote better understanding of and confidence in the procedures. Approved practices should be formally documented in a maintenance operations manual in ways that are clearly understood, along with the responsibilities of individuals at each organizational level. The manual should be supplemented with training sessions to guide and assist in the effective implementation of the practices.

Good management practices are particularly important with highway agencies in developing countries. Planning the work and making sure the work gets done is equally important to knowing how to perform the work in the field.

CHAPTER V

Utilization of Tools and Equipment

Countries that have been in the business of maintaining roads and bridges for quite some time have come to rely extensively on fleets or equipment for carrying out maintenance programs. Some developing countries are attempting to follow this pattern, with varying degrees of success.

Perhaps the biggest mistake of some developing countries is to believe that acquisition of large amounts of maintenance equipment will solve their problems. Unexpected high costs of equipment operation, spare parts, and repairs often compound problems by obligating large amounts of both foreign and local funds for current operations. When adequate funds are not available, the equipment deteriorates very rapidly, resulting in excessive down-time and a poor record of utilization.

The significance of this problem is well illustrated in a paper presented to the Pan African Conference on Highway Maintenance and Rehabilitation, held in Ghana in 1977. The authors of the paper were C.G. Harral and P.E. Fossberg of the Transportation Department of the World Bank. Excerpts from that paper include the following:

> ". . . When we recently reviewed performance under past highway projects financed by the World Bank in 43 countries we discovered that a uniform problem in almost all maintenance activities has been the poor utilization achieved from expensive, imported equipment. Not only does it require large amounts of scarce foreign exchange to purchase equipment, and usually a substantial amount of foreign technical assistance before local institutions can be developed, the importation of fuel and spare parts is often blocked altogether so that we have the specter of expensive equipment simply lying idle for long periods of time; in one country no more than 60 working days per year is being achieved, due in large measure to immediate constraints on the supply of fuel and spare parts. Increasingly the question has been raised as to whether these heavily capital-intensive, heavily foreign-exchange-dependent technologies are not inappropriate to the needs of the developing countries. The results of research done over the past six years strongly indicate that labor-intensive or intermediate technologies can be technically and economically feasible for the principal tasks of civil construction and maintenance in those countries where labor is abundant provided that due attention is paid to effective organization and management, to the use of proper tools and to the health and nutrition of the work force. Only the tasks of long-distance haulage (generally 5 kilometers or more), and high-quality compaction and finishing (as in asphalt concrete surfaces) are necessarily more economical by equipment-intensive methods . . . ."

This chapter will discuss some of the factors which should be considered by a developing country before making a commitment to highly mechanized operations. Guides will be presented for the effective use of hand tools and for improvised small units of equipment. Criteria will be set forth for necessary management practices related to fleets of maintenance equipment.

MECHANIZATION CONSIDERATIONS

Developing countries frequently have been tempted to acquire mechanized equipment for road and bridge maintenance. Often they are encouraged by available loans or grants from various international agencies. For some countries the programs have proven realistic and effective; for others the results have been an economic disaster with little evidence of improved road conditions.

Policy decisions on the extent of mechanization for maintenance operations should be made only after careful evaluation of the costs, the economic and social consequences, and the feasibility of continuing funding for equipment programs. There are no fixed criteria to govern all situations, but the following factors should be considered.

Capital Investments

When loans or grants are readily available, the initial capital investment in equipment is less painful. But eventually units of equipment will need to be replaced, and it is not realistic to depend on continuing loans or grants for this purpose. There must be a practical local financing plan that recognizes the need for periodic replacement of obsolete equipment.

A reliable program of equipment maintenance and repair is essential to continuing effective operation of an equipment fleet. This means that servicing and repair facilities must be available. In most cases, considerable capital investment is needed for the construction of repair workshops and warehouses for parts and supplies, as well as for procurement of needed workshop tools and equipment.

Experience has shown that the initial acquisition of equipment should be accompanied by the purchase of spare parts and supplies, with a cost for those supplies and parts totalling about 20 percent of the value of the equipment. These spare parts are needed to assure continuing operation for the first few years.

Continuing Costs

A commitment to a mechanized maintenance program must be accompanied by a commitment to provide annual funding for operations. Such expenditures will include

1. fuel and oil,
2. spare parts and supplies, and
3. equipment workshop operations.

Recent rapid increases in the cost of fuel have had a significant impact on all highway agencies, particularly those in developing countries with limited resources. It does little good to invest in expensive equipment and then let it sit idle because there are insufficient funds for full-time operation. Furthermore, as operating costs increase, a closer look must be taken at the economics of alternative maintenance work methods that are less equipment oriented.

Social and Economic Impact

The only real justification for highly mechanized maintenance operations would include one or more of the following conditions:

1. certain maintenance operations can be performed more economically with equipment than with hand labor,
2. the quality of workmanship with equipment is much better than with hand labor, and
3. there is a shortage of available and appropriate labor.

The third condition listed above seldom exists in developing countries. In fact, the opposite usually is true. Widespread unemployment encourages the creation of jobs in the interest of nationwide social and economic welfare. If this is the case, it is very difficult to justify a large equipment fleet without corresponding reductions in manpower, because the very nature of mechanized operations implies that an equal or greater workload can be accomplished with less manual labor. If the work force is not reduced, there can be no economic justification for extensive equipment utilization.

This is where problems arise. Understandably, officials find it very difficult to eliminate jobs and reduce the work force. But in the interest of overall economy and productivity, officials must be prepared to take these actions if policies are adopted for increased mechanization. Such decisions can have significant social and economic impact.

Trained Personnel

The effective use of equipment for maintenance operations requires considerable numbers of people who are trained and competent in equipment operation, servicing, and repair. In developing countries people with adequate qualifications usually are not readily available. This means there must be extensive training programs for equipment operators and mechanics. Various approaches can be employed, such as establishing local training centers, utilizing expatriate training specialists, and sending personnel to locations outside the country. In any case, training, which must be considered an essential part of transition to mechanization, can be a costly procedure. However, experience shows it can also be very costly to implement equipment operations without adequately trained operators and mechanics.

The problem does not end there. Highway agencies must be prepared to establish salary plans for operators and mechanics that are comparable with similar positions in local private industry. Where trained personnel is in short supply, and when highway agency compensation is not competitive with that of other employers, personnel turnover rates are extremely high. Agency training programs may turn out to be most beneficial for employers other than the highway agency.

Establishing Policies

When all of the above considerations have been evaluated, and when realistic comparisons have been made of the estimated costs and available funding, decisions can be made about policies and practices for utilization of tools and equipment for road maintenance.

Numerous options are available, ranging from operations that are totally labor oriented to completely mechanized ones. Some middle ground between the two may be most appropriate, or a long-range plan may be established for a gradual transition to mechanization coordinated with the economic development and capabilities of the country.

These should be top-level decisions that are made objectively. Once they are made, they should be formally documented as policy statements to guide future actions of the highway agency. Work methods performance standards (Chapter IV) should reflect the decisions on equipment utilization. Changes can be made as conditions change, but at least there will be a plan that may deter excessive mechanization that could be costly and ineffective.

HAND TOOLS AND SMALL EQUIPMENT UNITS

Even the most developed countries started out at one time with road maintenance practices they would now consider to be primitive. But they got the job done at relatively little cost, using hand tools and homemade equipment. Nearly all maintenance work can be performed with hand tools alone, although more time and a larger work force may be required than when heavy equipment is utilized. However, the tools must be available when needed, and the work must be effectively planned, scheduled, and supervised.

This section will discuss hand tools and improvised small units of equipment. A more detailed description of work methods with hand tools is set forth in Chapter VI.

Hand Tools

Conventional hand tools include items such as picks, shovels, rakes, machetes, tampers, saws, hammers, and wheelbarrows. Some craftsmen, such as carpenters, may provide their own hand tools. However, most tools must be furnished by the highway agency. This means there must be some assigned responsibility within the agency for procurement and management of hand tools. These responsibilities sometimes are delegated to the headquarters maintenance organization. In more decentralized organizations, each district may procure, allocate, and control its own hand tools.

Periodic purchasing of tools in quantity through competitive bidding by local suppliers usually results in the lowest unit prices. Warehousing should be provided at the headquarters or district offices for maintaining a reasonable inventory of tools for allocation to work units as the need arises. Inventory control systems should be implemented, including means for identifying of agency-owned tools, records of purchases, allocations to work units, and clearly defined accountability for the security of tools. Broken tools should be returned to the warehouse for replacement or repair.

When the field organization involves maintenance depots (Chapter III) a small inventory of hand tools can be maintained at each depot to be checked out and returned daily as needed by each crew member. In the case of road section crews, a small supply of tools can be allocated to each

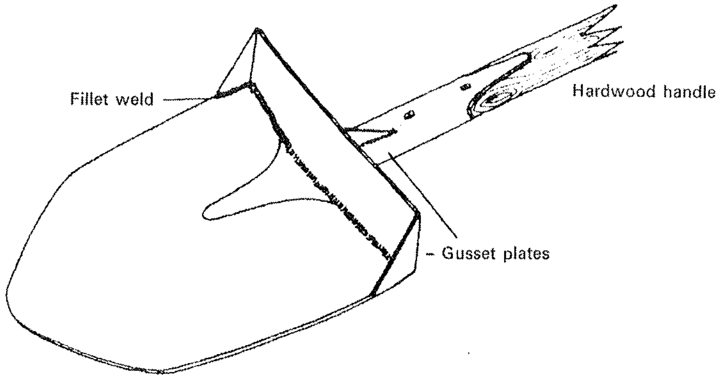


Figure 17. Spade for Barefoot Workers.


Figure 19. Animal-Drawn Cart (Philippines).

section foreman for reissuance to his crew members as needed.

In some cases, modifications may be needed in hand tools for effective use. For example, workers without shoes will experience difficulty pushing with their feet on the sharp top edge of common shovels. A small, flat footplate welded to the top edge at right angles to the blade (Figure 17) will make the work more comfortable and productive.

Hauling Equipment

Probably the first step toward mechanization will involve equipment for hauling materials. Wheelbarrows are considered efficient for hauls of about 75 meters or less. A well-designed wheelbarrow will have a pneumatic rubber tire and balanced design to lighten the load on the handle (Figure 18). For longer hauls some type of wagon or cart should be used. Simple two-wheel carts drawn by local animals can be effective for distances up to about 500 meters. An example of such a two-wheeled cart is shown in Figure 19. Pneumatic tires reduce the required tractive effort. Some carts have been built with bottoms consisting of bamboo mats or planks that are simply lifted to unload (Figure 20).

The loading, hauling, and dumping of materials for short distances can readily be accomplished with small scoop scrapers drawn by animals. Figure 21 shows a typical manufactured scraper. With a little ingenuity, comparable scrapers can be made from scrap metal, old oil drums or even bamboo.

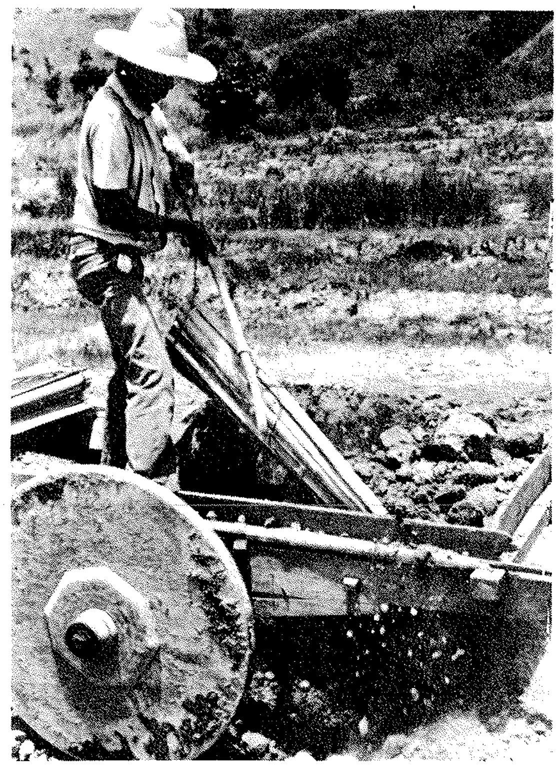


Figure 20. Unloading Animal-Drawn Cart with Bamboo Mat Bottom (Philippines).

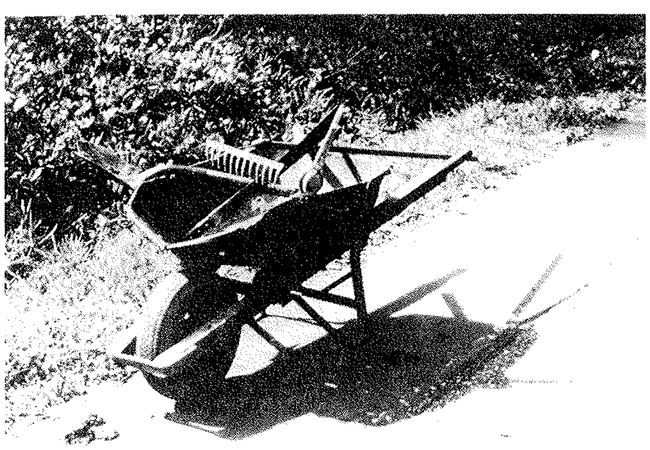


Figure 18. Wheelbarrow with Hand Tools.

The next advancement for hauling could be to substitute small, relatively inexpensive farm tractors for animal power, and to substitute a larger-capacity four-wheel trailer for the two-wheel cart. This can increase the productivity for longer haul distances.

The first real justification for full-scale mechanization in developing countries usually is found when there is frequent need for hauling large quantities of materials for distances in excess of about 8 to 10 kilometers. A small fleet of dump

Figure 21. Animal-Drawn Steel Scraper (Philippines).

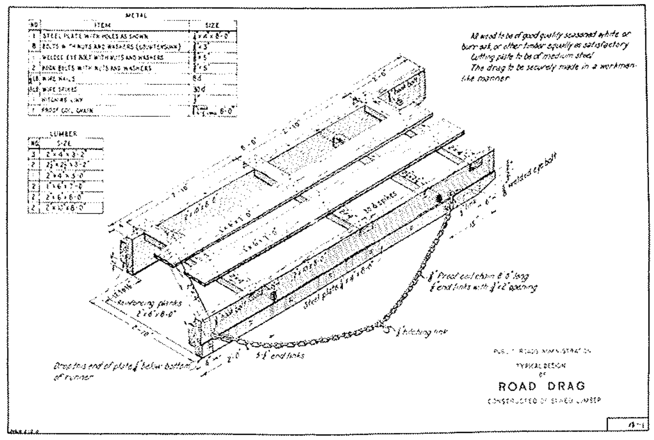


Figure 22. Typical Design of Road Drag.

trucks will be much more efficient than small carts or trailers. Typical situations would be hauling from quarry sites to roadway or stockpile locations, or from stockpiles to job sites.

Surface Smoothing Equipment

The motor grader is generally accepted as the most effective unit of equipment for shaping and smoothing unpaved surfaces. But motor graders are very expensive, and operators must be well trained and experienced to attain a satisfactory quality of workmanship. There are alternatives for maintenance of unpaved road surfaces which should first be considered by developing countries, particularly for those roads in remote locations with lower traffic volumes.

Various types of simple, homemade devices can be pulled by animals, tractors, or trucks to drag and smooth the surface. Figure 22 shows the design of a drag constructed with sawed timbers with a steel plate attached in front for a cutting edge. Figure 23 illustrates a drag constructed from angle iron and other scrap metals. Other similar designs can readily be fabricated at little cost. The principal criteria are one or more flat cutting edges arranged so they may be pulled at a slight angle to the roadway, and enough weight so there will be some cutting action without floating over the surface. Local roads that are rather soft, without a hard crust, can be smoothed reasonably well with simple drags of timbers, logs or heavy brush. Use of these devices is described in Chapter VI.

HEAVY EQUIPMENT

This section is directed to those highway agencies that are already highly mechanized for road maintenance, or that have made policy decisions to acquire extensive fleets of maintenance equipment. For the purpose of this synthesis, heavy equipment includes dump trucks, motor graders, front-end loaders, bulldozers, rollers, and other motorized units commonly used in road maintenance and rehabilitation work.

Because of the significant amount of initial expenditures and continuing operating costs for heavy equipment, it is particularly important to insure that the equipment will be used effectively. Practices for management and control of mechanized equipment are considerably more complex than for labor-oriented operations with hand tools. The following sections will discuss why these management practices are so important, and will present some general criteria on how the practices may be implemented.

Defining Equipment Needs

Equipment needs are described in terms of two criteria: (1) the types of equipment and (2) the numbers of each type. Frequently, a developing country produces a list of equipment needs (sometimes with consultant assistance) based on some rules of thumb which consider factors such as kilometers of roadway and numbers of field work force units. When the equipment is received and put to work it is often found that the types acquired are not the most appropriate, and the numbers of each type may be more or less than the actual needs.

The type of annual work program described in Chapter IV represents a very realistic basis for estimating equipment needs. It makes positive commitments on the specific maintenance operations to be performed, and identifies the equipment to be used for each operation, based on carefully considered work methods formally adopted by the agency. For example, the total number of motor graders required by a district can be calculated by referring to the adopted work methods standards and to the annual work program for the district. The following should also be identified:

1. each maintenance activity that requires a motor grader,
2. the number of annual crew-days scheduled for each of the maintenance activities,

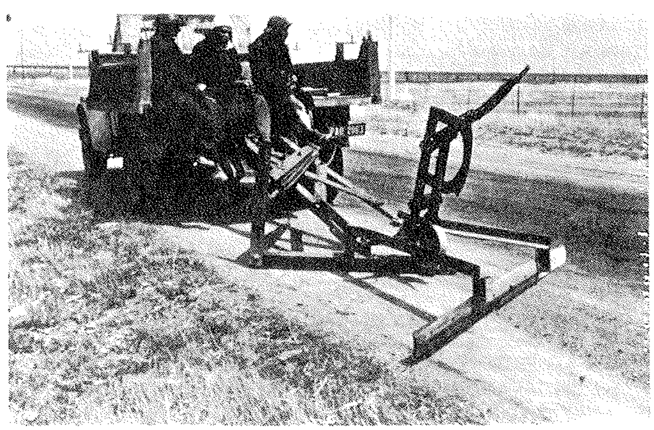


Figure 23. Metal Road Drag Shaping Road Surface (East Africa).

3. the number of motor graders to be assigned to each crew as set forth in the performance standards,
4. the estimated number of motor grader days required to accomplish the work,
5. an allowance for equipment down-time needed for servicing and repair, and
6. the estimated number of available working days during the year.

With this information, a realistic estimate can be made of the number of motor graders that should be assigned to a particular district. Similar calculations combined from other districts would permit estimation of nationwide needs for motor graders. Illustrative calculations are shown in Figure 24. Similar calculations will define needs for other types of equipment.

One other consideration for equipment needs is that the size and power specifications are appropriate for the job to be done. For example, there are several sizes of dump trucks. A relatively small (and less expensive) truck will serve adequately for many activities involving small quantities of materials and short hauls. On the other hand, trucks with larger capacity and more power are more economical when considerable quantities are to be hauled long distances. Loaders should be matched in size to the trucks. The same situation applies to motor graders. A relatively light unit with low horsepower can be perfectly adequate for most routine maintenance operations but may be totally inadequate for heavy construction work. Because of the much higher cost, it would be uneconomical to use the more powerful, heavy motor grader on most maintenance work.

The work to be done must be carefully considered from the work program. Equipment units of the right size and power must be selected to accomplish the work most economically.

Procurement Practices

A headquarters organizational unit normally is responsible for equipment procurement including (1) the preparation of specifications and tender documents, (2) advertising for bids, (3) the evaluation of bids received, (4) the award of purchase contracts, and (5) the receiving and inspection of delivered equipment.

Points to be kept in mind by those responsible for equipment procurement are as follows:

1. The preparation of lists of equipment to be purchased should be coordinated with the field units who will be using the equipment, and should be based on the comparison of the inventory and condition of the existing fleet with the equipment needs identified in approved work programs.
2. Special care should be taken so that specifications clearly show the desired characteristics of the equipment with respect to size, capacity, horsepower. and performance criteria. Loose specifications may result in equipment that is inappropriate for the job.
3. Policies and criteria for evaluating bids should be formally established so that both the suppliers and the highway agency evaluators understand the procedures. A point system that considers both price and performance characteristics works well.
4. In the evaluation of bids, some agencies consider the advantages of maintaining reasonable uniformity in equipment. For example, the problem of procuring and warehousing an adequate supply of spare parts for a particular type of equipment such as dump trucks is greatly simplified if the truck fleet is limited to units from one or two different manufacturers rather than a wide variety of different models.

When a developing country decides on a transition to mechanized maintenance operations, the procurement program should be planned in stages over a period of several years rather than relying on a single purchase to satisfy the estimated needs. Reasons for staged procurement are as follows:

1. The initial efforts to prepare performance-based work programs may not accurately reflect long-range equipment needs. A few years experience in programming will permit refining of equipment needs.
2. Initially, there may be some uncertainty as to the most appropriate size and specifications for particular units of equipment for existing local conditions. Observation and evaluation of the performance of the initially purchased units may indicate some changes are necessary for future purchases.
3. It will take some time for the equipment servicing and repair function to gear up to care for the new equipment. During the initial period of preparation and training it will be better to concentrate on fewer numbers of equipment, then gradually build up to an increased workload.

A suggested approach is to select one district as a test area, procure equipment for that district, conduct orientation and training of operators, servicemen, and mechanics, then observe and evaluate the performance under controlled conditions for a short period of time. Based on this experience, the equipment fleet can be expanded nationwide with greater confidence.

Once the equipment fleet has been established, plans should be made for regular periodic equipment purchases (perhaps annually) for needed replacement of obsolete units or for expansion of the fleet.

Figure 24

ILLUSTRATIVE CALCULATION OF MOTOR GRADER NEEDS FOR A DISTRICT

DISTRICT WORK PROGRAM

Maintenance Activity	No. of Annual Crew-Days	No. of Graders Per Crew	Total Motor Grader-Days Required
Blading Surfaces	1,200	1	1,200
Reshaping Ditches	300	1	300
Gravel Resurfacing	800	2	1,600
			3,100
Down-Time Allowance for equipment servicing & repair (15%)			+ 465
		Total	3,565

Estimated Non-Working Days	
Weekends	112
Holidays	13
Bad Weather	40
	165 days

Estimated Working Days
365 − 165 = 200 days

Required No. of Motor Graders
3,565 motor grader-days ÷ 200 days = 17.8 units (Round to 18 motor graders for the district)

*Equipment servicing & repair.

Inventory Control

Because of the sizeable investment in equipment, there is a need to establish and maintain a reliable system of equipment inventory and control. This means that those agency officials who are responsible for equipment must know at all times where each unit is located, its condition, and who is responsible for scheduling its operation.

A key to inventory control is some type of readily understandable numbering system where each unit is assigned a specific number. A system commonly adopted by many highway agencies consists of a three-digit number with a two-letter prefix. The prefix identifies the type of equipment. For example, MG might indicate motor graders, and FL might be used for front-end loaders. Other similar combinations of letter prefixes are assigned for each particular type of equipment in ways that are readily recognized. The three-digit numbers are assigned in chronological order as equipment is purchased; thus MG-001 would identify the first (and oldest) motor grader in the fleet, and subsequent numbers in the series would indicate the relative newness of other individual units.

Primary inventory records should be maintained in the headquarters office and should show equipment numbers, date purchased, location assigned, and individual to whom assigned. Changes of location should be recorded, and notations should be made of the disposal of obsolete units.

Equipment Servicing and Repair

Nearly all developing countries find it difficult to carry out adequate programs of equipment servicing and repair. Relatively new units of equipment can become inoperative because of improper operation or servicing. They are then sidelined waiting for spare parts, and by the time the spare parts arrive, the new unit of equipment has been cannibalized for parts to be used on other pieces of equipment.

Four factors contribute to these problems:

1. workshop facilities often are makeshift and inadequate, without necessary tools and workshop equipment;
2. inventories of spare parts and supplies are nonexistent, or so limited that seldom is a needed part readily available, and bureaucratic procurement practices cause a long delay;
3. workshop personnel often are not adequately trained for many servicing and repair operations; and
4. systems and procedures for effective management of workshop operations have not been developed or implemented.

Before large numbers of equipment are acquired, a highway agency should take steps to assure adequate facilities and procedures for equipment servicing and repair. Typically, three levels of workshops are established: (1) a central workshop with capabilities for major overhaul and repairs, (2) district workshops capable of performing the most common servicing and repair operations, and (3) subdistrict service shops for normal periodic servicing and occasional minor repairs and adjustments. Because of the considerable capital investment required, developing countries frequently use foreign loans or grants to establish or improve these facilities.

A formal program of preventive maintenance should be established for the equipment fleet. This would include a checklist for each type of equipment showing the inspections and servicing to be performed daily by the operators, as well as the servicing to be performed at prescribed intervals by service shops. Moreover, there should be policies and procedures to assure that the prescribed preventive maintenance program is consistently carried out.

Training programs should be designed and implemented for mechanics and servicemen as well as for shop superintendents. Shop management practices should be established for the scheduling and control of work. Developing countries commonly seek the guidance and assistance of expatriate experts for organizing and establishing the equipment servicing and repair function.

Equipment Utilization Data

Management must know how equipment is being used. Perhaps more important, managers should know when and why equipment is not being used. Idle equipment costs money. A basic management objective should be to attain maximum use for each piece of equipment.

One source of information on equipment utilization is the crew-day card or the weekly maintenance report described in Chapter IV. These reports are prepared by field work forces and show the work performed each day as well as the specific units of equipment that are used. Rates of utilization can be computed by summarizing these reports and dividing the number of days (or hours) of equipment use by the total number of available days (or hours) during the period. Utilization rates of about 85 percent or higher are generally considered acceptable. Rates below about 50 percent should be thoroughly investigated.

One inadequacy of the regular work reports is that they do not identify why certain units of equipment are not being used. To overcome this, some agencies require a monthly equipment report from each field management unit (district or sub-district). The report lists all pieces of equipment assigned to the unit and shows equipment usage by days or hours. Additionally, the report explains non-usage on particular days in terms such as (1) no work required, (2) servicing and repair, or (3) waiting for spare parts.

Review and analysis of these utilization data will help managers make proper decisions on

1. the types and numbers of equipment to be included in future acquisition programs.
2. more effective allocation of units among field work forces,
3. sharing of lightly used equipment among several field units,
4. upgrading spare parts inventory to reduce the amount of down time, and
5. improving the scheduling of equipment servicing and repair operations.

Equipment Costs

Reliable data on the costs of owning and operating equipment is needed for effective management practices. With mechanized operations, equipment costs reflect a large portion of the costs of maintenance programs. Three types of costs must be condsidered:

1. *operating costs* that include the fuel, oil, lubrication, and servicing needed to keep the equipment in operation;

2. *repair costs* that include the labor, parts, and supplies needed to repair inoperative equipment, including overhead costs of the repair shops; and
3. *depreciation costs* that reflect the loss of value of equipment during its normal economic service life (as short as five years or less for some types of equipment).

Operating costs usually are recorded through daily or weekly reports by equipment operators or service shop personnel. Repair costs are documented on job sheets prepared in the repair shops. Depreciation costs are computed as the difference between original cost and the salvage value, expressed as a percentage or as an annual cost.

Costing systems in most highway agencies are centered around equipment rental rates established for each class and size of equipment. Rental rates are usually expressed in terms of costs per hour, costs per day, or costs per kilometer. They are computed by dividing the total annual costs (operating, repair, and depreciation) by the total annual usage (hours, days, or kilometers). For this purpose, the concern is not for individual units of equipment, but rather for the average of a particular class of equipment. The rental rate values can be used for budget estimates, allocating resources to field units, and for identifying the actual costs of individual maintenance operations.

Cost data also are maintained in the records of individual units of equipment to identify units that have unusually high repair costs. The high costs may be due to old age and obsolescence, or may be attributable to negligence and abuse on the part of operators.

Equipment Financing Practices

After a developing country has made a decision to procure equipment for road and bridge maintenance, decisions must be made on how a continuing equipment program is to be financed. Sometimes when initial purchases are financed with foreign loans, little attention is directed to future financial obligations.

There are two practical approaches for financing these on-going equipment costs. The first and most direct approach is to recognize and include in each annual budget the estimated funds required for each of the three equipment costs.

The budget would show line items for

1. fuel, oil, and other operating costs;
2. labor, spare parts, and supplies for workshop operations; and
3. purchase of new or replacement equipment.

This is perhaps the most common financing approach. The principal difficulty in developing countries is that these costs often are underfunded, resulting in shortage of fuel for operation, lack of spare parts for repairs, and inability to replace equipment when it has become economically obsolete.

The other approach is to make the equipment financially self-sustaining through charges made to users. Equipment rental rates are established per kilometer, per hour, or other appropriate indicator and based on the estimated costs for operation, repairs, and depreciation. Each organizational unit includes estimates of equipment usage in its own operating budget. As usage occurs, the funds are transferred to the equipment function, providing continuing financing of equipment operation, repair, and replacement. Annual budgets do not include separate items for the equipment function itself. This approach is a little more complex, but if properly administered, can provide a sound, equitable way of equipment financing. The revolving funds thus provided serve multiple purposes: (1) to make operations more flexible, for instance in facilitating expeditious purchase of spare parts, and removing cumbersome pre-audit requirements of regular government procedures; (2) to discourage diversion of equipment to non-road uses, a major problem in some countries; (3) to enable trends in the efficiency of equipment maintenance and operation to be assessed and monitored, so that management can act expeditiously to bring down costs; (4) to promote awareness within the highway department of the high cost of equipment (most simply by an hourly use charge) and thereby encourage economic utilization; (5) to offset any possible distorted decisions (e.g., against labor-intensive operations or against contracting work out to the private sector); and (6) to reach the stage of being able to finance equipment replacement, to facilitate such purchases, and to encourage decreasing reliance on foreign loans.

CHAPTER VI

Maintenance Work Methods

There are several important reasons for adopting standard work methods for individual activities.

1. Without standard work methods, the quality of materials and workmanship may vary considerably among field units. Individual crew supervisors will have different ideas about how to perform the work as well as the desired quality of workmanship.
2. Under a given set of conditions there usually is a best way to perform the work from the standpoint of costs and productivity. Certain procedures and combinations of manpower, equipment, and material will assure the most effective utilization of resources for maintenance.
3. When the kinds and amounts of maintenance activities are planned in advance for an annual program, standard work methods and average productivity rates are necessary to estimate the needed resources and funding for the program.

This does not mean that maintenance work methods standards will be the same for all highway agencies. Differences in climate, terrain, soils, field organizational practices, and the extent of mechanization may vary appropriate work methods.

Individual agencies should carefully consider their own unique conditions when adopting standard work methods. Adopted standards should be clearly documented in directives or manuals for field personnel. Programs of training and supervision should encourage field units to follow the standards. If better and more effective methods are found, the standards should be revised.

This chapter will discuss detailed work methods for specific maintenance activities, along with alternative approaches for particular conditions.

SURFACE MAINTENANCE

The principal objectives for maintaining unpaved surfaces are (1) to keep the surface reasonably smooth, firm, and free of excessive loose material; and (2) to maintain the proper roadway crown for surface water runoff. The various activities directed to these objectives are discussed in this section.

Surfacing Materials

Some surface maintenance activities involve the addition or replacement of surfacing materials. Before talking about maintenance work methods, we should first look at some criteria for surfacing materials. The quality of these materials can have an important influence on the effectiveness of maintenance operations.

Surfacing of unpaved roads can range from the natural soils in the area to carefully graded crushed aggregate. Sometimes the natural soil has characteristics that provide a reasonably stable wearing surface — usually it does not. Under any condition, careful consideration should be given to the quality of the materials initially employed in or added to an unpaved surface.

Compendium 2, *Drainage and Geological Considerations in Highway Location,* published in 1978 by the Transportation Research Board, includes sections on Subsurface Soils Exploration and Field Identification of Soils and Aggregates. This source provides an excellent basis for classification and rating of soils and aggregates as road materials. These published techniques should be employed by highway agencies for evaluating local soil conditions and for locating potential borrow sites for surfacing materials that have desirable characteristics.

When roadside materials prove acceptable, they may be used economically as surfacing material. When the material is unacceptable, arrangements should be made to import selected natural surfacing materials or crushed aggregate from the nearest approved sites. Some agencies stockpile supplies of surfacing materials at convenient locations along roads for future use in maintenance operations.

One of the best wearing surfaces seems to be a combination of different sizes of aggregates blended together with the largest size usually no more than about 2 cm. The pieces lock and pack together to make a strong, tight surface. Fine material is added to fill the voids and serves to hold the aggregate together.

The added cost of good quality surfacing materials usually results in overall savings through longer lasting maintenance repairs.

Mechanical Blading and Shaping

Periodic smoothing and reshaping is the most common maintenance operation for unpaved surfaces; it produces the most obvious improvement for motorists. The motor grader has become the generally accepted piece of equipment for this operation. Even countries that have not become highly mechanized usually have several motor graders available with which to blade their more important roads.

A less expensive approach is available for mechanized blading. It employs underbody blades mounted on trucks. The equipment is hydraulically operated from the cab and is usually mounted on four-wheel drive trucks to provide adequate power. These units are not as effective as a motor grader for blading operations, nor can they effectively blade ditches, but their availability for use as a truck gives added versatility to the overall equipment fleet.

This synthesis does not give details for operation of a motor grader or any other particular kind of equipment. It is assumed that some basic operator knowledge and skills currently exist, or will be provided through training. Rather, the synthesis emphasizes how equipment might be used most effectively for particular operations. Compendium 5, *Roadside Drainage*, and Compendium 7, *Road Gravels* (Transportation Research Board, 1979), provide more detailed information on actual motor grader operations.

Normal deterioration of unpaved surfaces usually results in one or more of the following conditions which need periodic correction:

1. transverse corrugations;
2. longitudinal rutting;
3. erosion from surface water;
4. loss of crown elevation at the center line, with build up of loose material along the shoulder; and
5. potholing.

Figures 25 and 26 show typical examples of unpaved surface deterioration, including rutting, potholes, and soft spots with standing water.

The frequency for scheduling repairs depends on the characteristics of the surfacing material, rainfall, availability of capillary water to keep the surfacing material moist, traffic volume, and the level-of-service standards for each of the various road classifications.

Moisture conditions greatly influence the effectiveness of blading and shaping operations. Little work can be ac-

Figure 25. Unpaved Surface Deterioration.

Figure 26. Unpaved Surface Deterioration.

complished during very wet periods, and it is extremely difficult to get any good results when the surface is very dry and hard. The best time to schedule the work is during or shortly after a rain or following the rainy season when the surface is reasonably firm, and yet has enough retained moisture to facilitate easy cutting, moving, and compaction of materials. Without this moisture to bind the surface, it will not long remain smooth and corrugation free.

Blading and shaping often is a single-unit operation, with one motor grader and one operator. Some agencies effectively use two units working in tandem, with the second unit overlapping the blading path of the first. Also, two or three laborers should be assigned to the operation for occasional hand raking and smoothing, and for picking up and disposing of oversize rocks that may become dislodged during the grading.

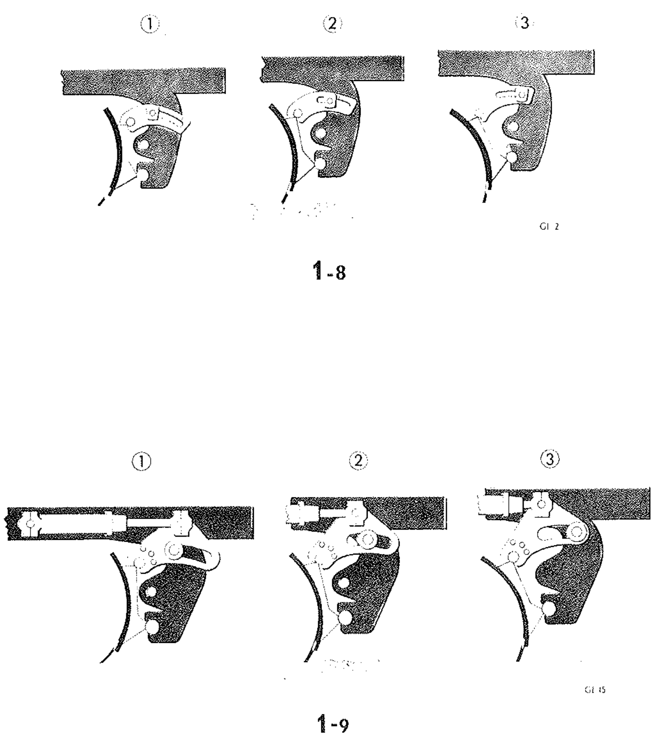


Figure 27. Grader Blade Pitch Adjustments.

Adjustments in the vertical angle of the blade permit different types of operations (Figure 27) as follows.

1. When a cutting action is needed, the blade should be set back at the top and forward at the bottom cutting edge. In this position, corrugations and high spots can be cut down.
2. For most normal grading work, the blade is set in a more vertical position.
3. When a spreading or dragging action is needed, the top of the blade should be set forward. A dragging rolling action created by the curve of the blade helps smooth and compact the surface.

One of the most important functions of the blading and shaping operations is to restore and maintain proper roadway crown so that surface water will drain off as quickly as possible. How much crown slope is best? For soil-aggregate surfaces the slope should range between about 2 to 4 percent. Thus the surface should slope down 2 to 4 centimeters for each meter of width between the centerline and the shoulder. Less slope is needed for a porous, sandy soil because it tends to absorb moisture without softening the surface. Clay soils should have a steeper slope.

On curves the normal crown slope is replaced by a superelevation slope, i.e., one continuous slope from the shoulder on the outside of the curve down to the inside shoulder. Superelevation serves two purposes. It provides for safer operation of vehicles around the curve, and also takes care of surface water runoff. Superelevation slopes may be a little steeper than normal crown but should not be over 5 or 6 percent. When slopes are very steep, the water may run off too fast and result in erosion of the surface. Particular care is required in shaping the transition in cross slopes between tangents and curves.

Slope can be measured by motor graders that have a crown guage mounted on the instrument panel. If this is not available, a simple homemade crown board can be constructed for the desired slope. Used with a carpenter-type level, the board shows the cross slope to the motor grader operator so that adjustments can be made to flatten or steepen the slope as needed. Figure 28 illustrates use of the crown board for checking the slope.

During motor grader operations, the blade is angled horizontally so that one end is slightly forward and the other to the

Figure 28. Checking Slope with Crown Board (Ghana).

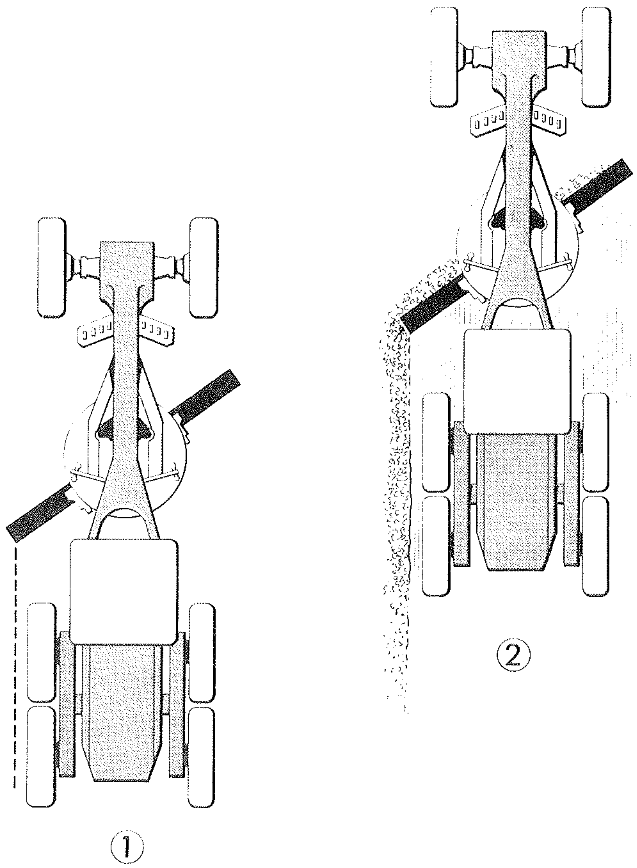


Figure 29. Correct Horizontal Blade Position for Forming a Windrow.

rear. Aggregates roll to the back end of the blade and any excess forms a windrow (Figure 29). The first passes with the motor grader should be along each shoulder so that excess material from each side is brought to the center in a windrow. This operation is illustrated in Figure 30. Additional passes are then made with a dragging action of the blade to spread and compact the windrowed material back across each side of the roadway (Figure 31), with special care taken to provide the desired crown shape.

Where adjacent natural soils are of adequate quality, the first pass of the motor grader may start in the roadside gutter

Figure 31. Spreading a Windrow (Ghana).

or ditch to retrieve materials to build up the surface elevation. Care should be taken to avoid contamination of existing good quality surfacing with inferior material from the ditches.

Sometimes a hard crust forms along with deep rutting, potholing, and corrugations — a crust that may not cut easily with the grader blade. Under these conditions, a scarifier attachment on the grader is used to break up the existing surface before the blade is used for reshaping and smoothing.

When using a scarifier on natural soil roads, or on aggregate surfaces when oversize material has not been removed, there is a tendency for large rocks and other oversize material to come to the surface. These objects should be removed before attempting to smooth and shape the surface. Otherwise these large rocks catch under the blade and tear the surface.

With a well-trained and experienced operator, periodic blading and shaping with a motor grader usually produces the highest levels of maintenance service as shown in Figure 32. But other approaches may be more desirable and economically appropriate for some agencies.

Hand Tools and Drags

When motor graders are not available, or when it is the adopted policy of an agency to utilize manpower as extensively as possible, regular smoothing of unpaved surfaces

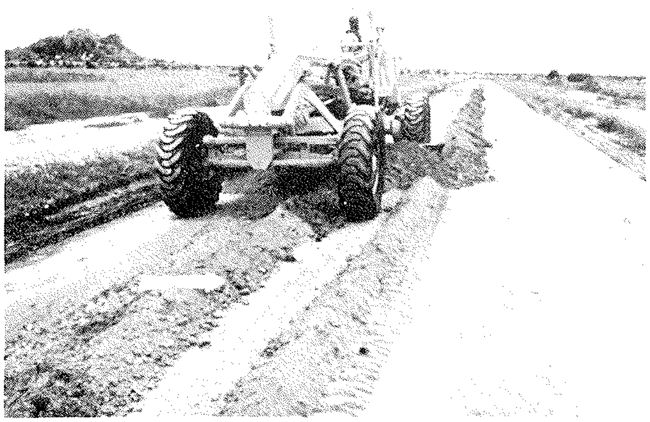


Figure 30. Forming a Windrow (Ghana).

Figure 32. Completed Roadway Surface (Ghana).

can be accomplished entirely with hand tools. This is particularly applicable in remote areas for roads with low traffic volumes and where local maintenance crews are responsible for a particular road section.

Corrugations, ruts, and loose gravel can be leveled and smoothed with hand picks, shovels, and rakes. More time and manpower are required by this approach, and generally the results are not as satisfactory as with a motor grader. But a lesser level of service is acceptable for some classes of roads, and the costs usually are considerably less.

Highway agencies have found that some simple homemade tools and equipment are effective for the smoothing and shaping of unpaved surfaces. Numerous types of homemade drags have evolved which are quite effective for sandy surfaces, but may be somewhat less effective in rocky soils and hard crusted surfaces.

The simplest drags might be timbers, logs, or heavy brush used to smooth the surface. More sophisticated devices are made of scrap metal, or wood with metal cutting edges. Sometimes additional weight is added. They are pulled by animals, small tractors, or by trucks. Some examples of these devices are illustrated in Chapter V (Figures 22 and 23).

Dragging is primarily for the purpose of filling in ruts and smoothing out irregularities in the surface. Unquestionably, the motor grader does more precise work for reshaping the surface and restoring crown. But by controlling the blade shape and angle on some of the better drags, excess materials can be moved from the shoulders to the center and thus provide reasonably good reshaping and smoothing of the surface. The sequence of operations is essentially the same as with the motor grader except that it probably will be necessary to make more passes with the drag.

In addition to the operator of the truck or tractor which pulls the drag (or the handler of the draft animals), additional laborers with picks and shovels usually are needed to loosen hard crusted materials and to remove oversize rocks.

As with blading, dragging is most effective with a small amount of moisture in the soil—not too wet, not too dry. For a comparable level of service, it is found that dragging usually must be performed at more frequent intervals than blading with a motor grader. There is great opportunity for innovation in the design, construction, and use of homemade drags for smoothing and shaping unpaved road surfaces.

Ideally, a reshaped gravel road should be compacted with a smooth-wheel or rubber-tired roller, but this is usually too costly. An alternative is to compact the surface with repeated passes of a heavy truck. In most cases, compaction is left to vehicles traveling the road—a practice that is not very satisfactory because compaction is limited to commonly used wheel tracks and does not cover the entire surface.

Patching

Problem areas often develop in unpaved surfaces at small isolated locations, while most of the roadway section remains in reasonably good condition. Examples of these problems might include soft spots (Figure 33) caused by unstable material, potholes, and surface erosion. These conditions usually require patching with additional surfacing material.

Previous discussions emphasized the importance of the quality of surfacing materials used in road maintenance. This should be remembered even with simple patching operations. Roadside materials should be used only when they are of acceptable quality. Otherwise, patching materials should come from designated pits or from nearby stockpiles established for that purpose. All oversize material should be removed before placing the surfacing on the road.

Figure 33. Typical Soft Spot Requiring Patching.

Even in the more developed countries, patching is primarily a labor and hand tool operation. Trucks may be used for hauling materials, but the material is usually spread and compacted with hand tools. In the case of very large patches, motor graders may be used for spreading materials and rollers for compaction.

If the problem involves soft unstable spots, two things should be done before new material is added.

1. A check should be made to see if the problem is caused by water. Excess water in the subgrade caused by ponding along the roadside often causes instability. It may be necessary to revise drainage ditches, construct new outlet ditches, install a culvert, install perforated pipe underdrains, or even raise the level of the roadbed.
2. Any material with unstable characteristics should be excavated and disposed of so that new material will be of a depth adequate for the needed support.

When trucks are not available other implements may be used to haul patching material to the work site, including animal-drawn carts, wheelbarrows, and even baskets. Trucks are more appropriate if the haul distance is very far.

Patching materials should be placed in the holes in several layers, each not to exceed about 6 to 8 cm. This permits each layer to be firmly compacted in place, and is more effective than trying to compact the entire depth of the patch. Compaction will result in greater density (and better results) when water is added so that the material is near the optimum moisture content.

Tools needed are shovels to move the material, rakes to spread it evenly, and some type of hand tamps to compact the material. In the case of very large areas to be patched, drags may be used to spread, shape, and level the material.

The need for patching is greatest during and immediately following extended rainy seasons. It is extremely difficult to place good quality patching when the surface is wet. But from the standpoint of safety and comfort of motorists, some type of temporary repair is needed. Under these conditions, temporary patching should be scheduled without concern for careful layering and compaction of material. This will alleviate hazardous conditions until permanent repairs can be made.

Extensive permanent patching should be scheduled when road surfaces have dried out sufficiently.

Resurfacing

One of the characteristics of unpaved roads is that surfacing materials are lost over a period of years through the combined actions of traffic, surface water runoff, and windblown dust. Under average conditions, this can amount to about 2 cm of depth in a year.

If lost material is not replaced on natural soil roads, the surface elevation gradually becomes lower and lower until it may be below the adjacent ground level. When this happens, deterioration accelerates because the roadway itself often becomes a drainage channel. When imported aggregate surfaces decrease in thickness, there is a loss in the strength and stability of the riding surface. Therefore, resurfacing operations for long continuous sections of unpaved roads need to be scheduled every few years. The frequency depends on the rate of loss of materials, which in turn depends on traffic volumes, characteristics of roadway surface materials, and weather conditions. The period between resurfacings may be as short as every year, possibly as long as 6 to 8 years or more. Observation and experience will help establish proper criteria for the various classes of roads for individual highway agencies.

The thickness of resurfacing courses are seldom less than about 8 cm and may be 15 cm or more. Thus surfacing material requirements may be well over 1,000 cubic meters per kilometer of road. The length of major resurfacing projects may be as short as a few kilometers, or they may be 20 or 30 kilometers long.

Because of the large volume of materials normally involved, resurfacing is very difficult, but not impossible to accomplish solely with labor and hand tools. Some agencies establish mechanized crews that are equipped with dump trucks, loaders, motor graders, water wagons, and rollers. Many agencies find it more practical to perform this work through private contractors rather than to staff and equip their own crews.

The following work methods and procedures are set forth for agencies that are in a position to undertake resurfacing as a mechanized operation.

1. The existing surface should be shaped so that the new surfacing can be laid to uniform thickness and still have the appropriate crown. The crust of the existing surface should be broken, with a scarifier if needed, before the new material is spread.
2. The source of surfacing materials should be determined by laboratory testing, but should be as close as possible to the work site. It may be a rock quarry that requires a crushing plant, or a borrow pit of acceptable natural material. In the case of a crushing or screening plant, arrangements should be made for the proper blending of various sizes of material as described in Compendium 2, *Drainage and Geological Considerations in Highway Location* (Transportation Research Board, 1978). Elimination of large oversized material should be a part of the process.
3. One or more front-end loaders should be assigned to the material source site (crusher plant or borrow pit) to assure a balance of loading and hauling capacities.
4. The number of dump trucks to be assigned to the work will depend on the haul distance and the rate at which material can be spread and compacted on the roadway. Whenever possible, the material should be placed through a spreader box (Figure 34) to minimize segregation. In this case, too few trucks will delay progress at the work site, but too many trucks will cause inefficient delays in unloading. If spreading is by motor grader, the material can be deposited on the roadway for a short period of time before spreading.
5. The new surfacing material may be spread in one or more layers and should be compacted, preferably with a pneumatic roller. If the material is dry, water should be added with a water wagon to bring the material to near optimum moisture content. Choice among number of layers depends on the availability and weight of compaction equipment.

The foregoing procedures reflect the most desirable practices for maintenance resurfacing. When the equipment is not available, alternative practices might include (1) use of acceptable roadside material, (2) use of carts and wheelbarrows for hauling, (3) spreading with hand tools and drags, and (4) compaction by traffic.

Certain actions may be taken to reduce the frequency of resurfacing. Where relative humidity is high, use of dust pallatives during the dry season can reduce the amount of materials lost as dust. Application of a light bituminous surface treatment (sometimes called dust oil) can reduce both dust losses and losses from surface water erosion. The question is whether the savings in resurfacing will be greater than the costs of the preventive actions. Economic savings may result on some of the more important higher traffic volume roads, but is unlikely that these actions would be economically effective on many low-volume unpaved roads. Furthermore, tightly sealing the surface prevents the evaporation of moisture and may lead to severe potholing. Compendium 7, *Road Gravels* (Transportation Research Board, 1979), provides more detailed information about potholing.

DRAINAGE

Uncontrolled water can be one of the most destructive forces on rural roads. For this reason, designers of new roads

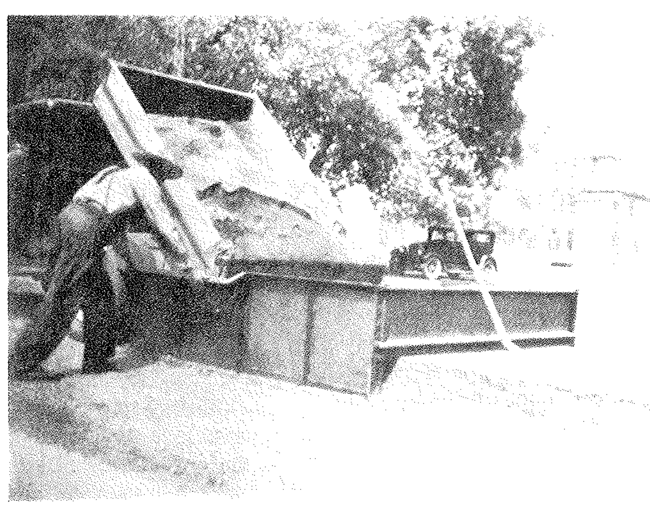


Figure 34. Spreader Box (reprinted by permission of John Wiley & Sons, Inc.).

carefully set the size and location of culverts and drainage ditches to assure the controlled flow of surface water in ways to avoid damage to the roadway or interruptions in the movement of traffic.

In urban areas, the drainage systems may include underground storm sewers with inlets, catch basins, manholes, and other appurtenances. Since this synthesis is concerned principally with rural roads, the discussion is limited mainly to culverts and ditches. With lack of proper maintenance, the following problems may arise:

1. The amount of water that can flow through a cross-drain culvert will be reduced if the culvert becomes partially clogged with debris (Figure 35). Water may back up at the culvert entrance and eventually overflow the roadway. This overflow, with enough water volume, may wash out an entire section of roadway.
2. Roadside ditches are intended to carry intercepted water along the road to discharges at cross-drain culverts or outlet channels. If these ditches become clogged, water will back up (Figure 36). Over a period of time the ponded water will saturate the roadbed, and decrease both strength and stability.
3. Outlet ditches are intended to channel water away from the roadway. When the flow is obstructed by vegetation and debris, water will back up and saturate the roadway, or possibly even overflow the surface.

Developing countries often have another special kind of drainage problem. Many of the roads were never really designed, they just grew from usage and a minimum of development. Drainage features were installed without a great deal of technical guidance as to location, capacity, and size. Problems therefore arise from inadequate initial installations rather than lack of maintenance. These situations can be corrected only by upgrading the drainage installations with betterment work. Often this involves raising the elevation of the roadway.

Work methods for the most common drainage maintenance operations are described in the following sections.

Cleaning and Repairing Culverts

The term "culverts" includes round metal or concrete pipes, and rectangular shaped wooden or concrete boxes. Cleaning of culverts is basically a manual operation with hand tools.

Figure 36. Standing Water in Roadside Ditch (Honduras).

The key to good drainage maintenance is regularly scheduled inspection and cleanout activities. Three types of inspection should be scheduled:

1. detailed inspection and cleanout of all culverts just prior to the beginning of each wet season;
2. casual observation of the operation of culverts and their inlets and outlets during the wet season to identify potential problem areas; and
3. detailed inspection after the wet season to locate any damages so that repair work can be scheduled during the dry season.

Accumulation of dirt and debris usually occurs at pipe inlets, and at a short distance inside the pipe from the inlet end (Figure 37). Seldom does the outlet end of a culvert become clogged unless the outlet flowline was constructed too low, the gradient of the culvert is too steep, or the outlet ditch itself becomes clogged.

When culverts are large enough for a man to walk or crawl inside, cleaning can be accomplished with shovels, brooms and other hand tools (Figure 38). For small diameter culverts, it may be necessary to extend the length of handles on tools so that material can be reached and dragged out. The material that is cleaned out is loaded in wheelbarrows for disposal. Debris should be disposed at locations where it will not again be washed to the culvert entrance. Dirt and granual material may be used to fill nearby eroded areas in slopes, but is usually unsuitable for roadway patching.

Figure 35. Cleaning Blocked Culvert (Indonesia)

Figure 37. Cleaning Culvert Inlet (Indonesia).

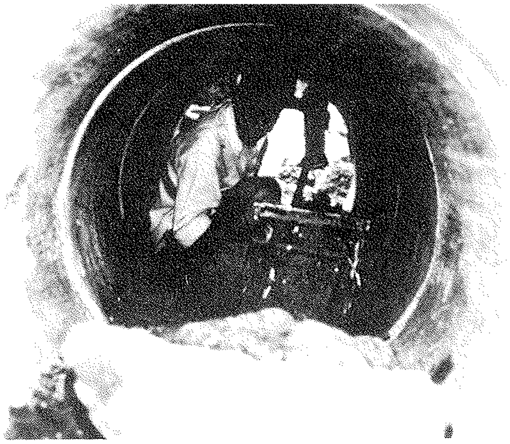


Figure 38. Cleaning Inside of Concrete Culvert (Honduras).

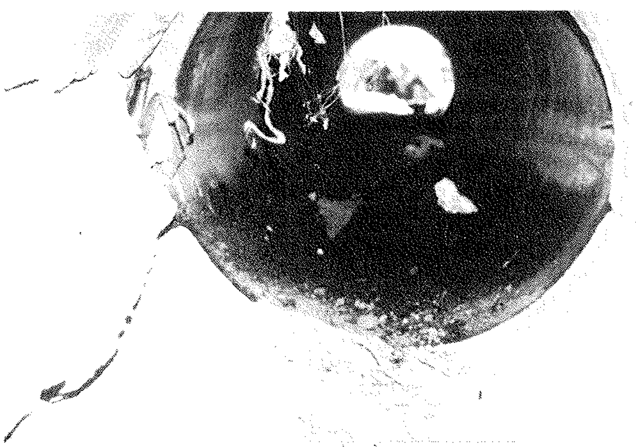


Figure 39. Broken Culvert Section (Honduras).

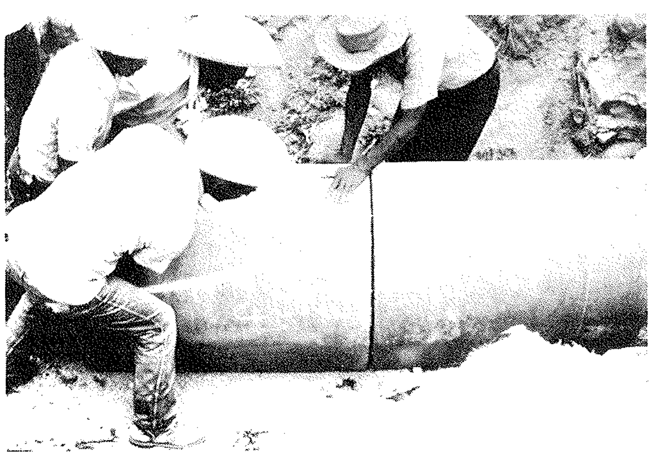


Figure 40. Culvert Section Replacement (Honduras).

At the time of cleaning, inspection should be made for any possible damages to the culvert itself. Repairs should be scheduled as soon as possible. Typical damages to look for include

1. broken or damaged end sections;
2. misalignment and possible broken pipe sections or joints, caused by settlement or heaving (Figure 39);
3. corrosion of the invert (bottom) of metal or concrete pipe; and
4. erosion of materials from the under the end sections, endangering the pipe.

Most culvert repair work is done manually with hand tools. Broken joints can be repaired with cement grout or metal clamps. Cement grout or asphalt cement can be used to pave the invert of corroded pipe and thereby extend service life. Broken sections of small diameter pipe can be replaced with new pipe sections (Figure 40). Beacuse of the weight of large diameter pipe, replacement of damaged pipe sections is difficult without some type of equipment capable of lifting, carrying, and lowering the pipe sections. Erosion around culvert ends can be repaired with rock and hand-tamped granular material as described in a following section on erosion control.

Cleaning of culvert inlet and outlet ditches should be performed along with culvert cleaning.

Hand Cleaning of Ditches

Two types of drainage channels need periodic cleaning and shaping: (1) ditches constructed adjacent and parallel to the roadway (Figure 41) to intercept surface water and carry it to locations where it may be discharged in natural channels, and (2) inlet and outlet ditches at culvert locations (Figure 42) where water in natural channels is carried under the road.

Cleaning and shaping is needed because water flow may be slowed or blocked due to growth of vegetation, accumulation of debris, rock and earth slides, and erosion of slopes.

All ditches should be cleaned at least once a year. The work should be completed before the beginning of the wet season.

Some agencies clean and shape ditches with mechanical equipment but the work is particularly adaptable to manual labor and hand tools in developing countries. The basic tools needed are machetes or some type of blades for cutting grass and weeds, together with picks, shovels, rakes, and wheelbarrows. Typical ditch cleaning operations with hand tools are shown in Figures 43 and 44.

In relatively level areas, the vegetation in ditches may be removed entirely to keep it from growing back to fast. When roadside ditches are fairly steep, it is better to cut the vegetation and preserve it to help prevent erosion. In this case it may be necessary to cut the vegetation several times a year.

The shape of roadside ditches is very important from the standpoint of both efficient drainage and ease of maintenance. Commonly these ditches have been V-shaped with rather steep side-slopes. When erosion occurs in a V-ditch there is a tendency for maintenance crews to deepen the ditch and to steepen the slopes. This is an undesirable practice. The original elevation of the ditch flow line should be maintained and the ditch slopes kept as flat as possible. Desirable ditch slopes, as shown in Figure 45, make it easier for maintenance crews to cut vegetation and clean the ditches. Deep side ditches with steep slopes can be extremely hazardous to motorists, as well as ineffective for drainage. Figure 46 shows a side ditch with well-shaped slopes and grade alignment.

Where considerable amounts of material must be moved in the process of cleaning and reshaping ditches, the work can be eased with a simple animal-drawn scraper. This scraper, guided by a laborer, can cut to the desired depth and shape and carry it to a point where it can be deposited or loaded in trucks or wheelbarrows for disposal.

Machine Cleaning of Ditches

Developing countries often will find the use of manual labor and hand tools to be the most appropriate approach for cleaning and shaping of ditches. However, the work can be accomplished effectively with various types of equipment.

The motor grader is probably the most common piece of equipment used for reshaping roadside ditches. Flexibility is provided by adjusting the angle and position of the blade to conform with the desired slopes and depths of the ditches. Figure 47 shows a typical ditch cleaning and shaping operation with a motor grader.

When the ditch is dry, the front and rear wheels on the right side of the grader are set in the ditch, and the blade is angled vertically so that material spills off the center of the blade, leaving a windrow between the rear wheels. In wet ground, the rear wheels should be on firm ground with the grader angled so that the front wheels are in the ditch, followed by the toe of the blade.

It is important to keep the ditch flow line at the elevation of original construction. The ditch bottom should be checked to make sure there are no low spots where water will collect (Figure 48). By side-shifting and rotating the motor grader blade, some of the windrowed material can be deposited in low spots in the ditch on the return passes of the grader. Usually, the operation will result in some excess material left in the windrow. This should be loaded in wheelbarrows, carts, or trucks, and disposed of. A small supplement of laborers with shovels and rakes can be used for final finishing and loading of materials.

If available, Gradalls are very effective for cleaning and shaping ditches, particularly when large amounts of materials can be loaded directly in trucks (Figure 49). Front end loaders can be used for removing excess material, but they are not very effective for reshaping ditches.

Cleaning of large ditches and channels that are dry usually can be performed best with bulldozers, scrapers, or loaders and trucks. When there is standing water, draglines or clamshells may be required. Where feasible the material is deposited as a berm along the channel. Otherwise, it is loaded and hauled away.

ROADSIDE MAINTENANCE

Within the roadway right-of-way several maintenance operations normally are required in addition to those that are directly related to the road surface or to drainage. These operations include vegetation control, correction and prevention of erosion, and in some instances, litter pickup.

Vegetation Control

Vegetation of concern to maintenance forces include grass, weeds, brush, and trees (Figures 50 and 51).

Figure 41. Typical Roadside Ditch (Sierra Leone).

Figure 42. Typical Outlet Ditch for Culvert (Honduras).

Figure 43. Typical Labor-Intensive Ditch-Cleaning Operation (Ghana).

Figure 44. Typical Labor-Intensive Ditch-Cleaning Operation (Ghana).

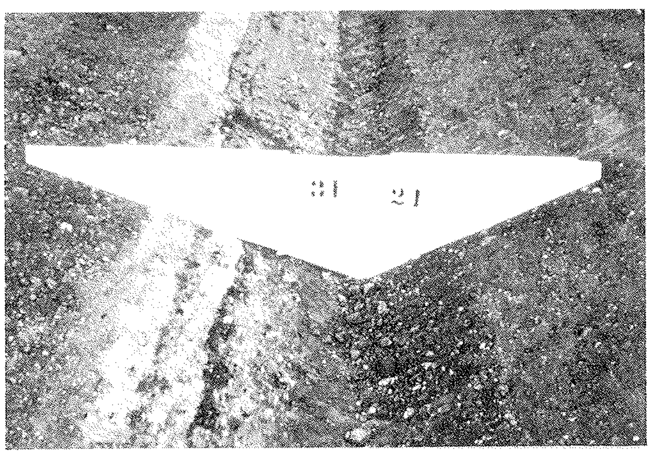


Figure 45. Desirable Ditch Slopes (Ghana).

Figure 46. Example of Good Slopes and Alignment (Ghana).

In the more developed countries, maintenance of grass is sometimes a very significant item. Often it is planted, watered, encouraged and mowed frequently for esthetic purposes. Mowing operations are highly mechanized. For low-volume roads in developing countries, mowing will normally be performed with hand tools such as simple mowers, scythes, and machetes.

In tropical climates, highway agencies often have problems with forms of vegetation that grow very fast. These are principally right-of-way encroachment by vegetation that interferes with normal drainage, obscures signs, reduces motorists' sight distance, and even interferes with vehicle operation.

The frequency of scheduling brush cutting and tree trimming depends mainly on the rate of growth. Most agencies plan the work for at least once a year, sometimes more frequently. Maintenance supervisors should inspect the road system periodically to identify locations where vegetation growth is creating problems. They should follow established policies that identify the widths for each side of the roadway to be cleared.

Brush cutting and tree trimming are almost entirely hand operations with axes, machetes, and hand saws. In some cases it may be economical to equip special crews with hand-held chainsaws. Where conditions permit, the cut material is piled and burned along the roadside. Where this is not practical, trucks or carts are used to haul the material to suitable burning sites.

Erosion Control

Erosion control involves both repair of eroded locations as well as actions to prevent future erosion. Previous sections discussed the repair of roadway surface erosion with patching, the repair of roadside ditch erosion with ditch cleaning and reshaping, and repair of erosion at culvert ends.

Another location where erosion commonly occurs is on roadway fill and cut slopes. Once erosion starts at these locations, it gradually becomes more serious until it is corrected. Repairs consist of hand placing and tamping some type of granular material in the eroded channels. But this will be only a temporary solution unless the conditions that caused the erosion are corrected.

In the case of eroded cut slopes, one of the best corrective actions is to construct a small interception ditch slightly above the top of the slope. A small V ditch with berm on the downhill side works well. Surface runoff is intercepted and is carried parallel to the top of the cut slope to the roadside ditch or to a natural drainage channel, thus diverting the water from the slope where erosion was a problem.

A similar approach can be used to prevent erosion of roadway fill slopes. A small berm or dyke is built along the shoulder to divert surface runoff to a point where it can be discharged without damage. Outlet points may be along the natural ground elevation and at intermediate down channels that are lined with rock or grout (Figures 52 and 53).

Some agencies effectively control erosion of cut and fill slopes by introducing a vegetation cover on the slopes. The vegetation is usually some type of native grass established by seeding or sodding. Surface runoff water is allowed to run down the slopes, but the vegetation and the established root system prevent serious damage.

Repeated erosion of ditches indicates that some preventive action should be taken. One approach is to line the bottom of the ditch with stone, or preferably stone and mortar grout. Another way of preventing ditch erosion on steep grades (over 3 percent) is to construct a series of small check dams in the bottom of the ditch. These may be made of logs, timber, or scrap sheet metal, with rock riprap on the downstream side to prevent erosion as the water goes over the barrier (Figure 54). The purpose is to slow the speed of the water and allow it to go down the ditch in a series of small steps.

The inlet and outlet ends of culverts seem to be particularly susceptible to erosion. Concrete wingwalls and aprons or rock riprap are the common protections. Outlet ends usually give the most trouble. Water leaving the culvert may erode a hole in the ditch, and even undermine the culvert itself. Some type of concrete or riprap apron (Figure 55) is particularly important here.

Roadway fills adjacent to streams often are subject to erosion—sometimes so seriously that the entire roadway may be washed away. The simplest correction, and prevention, is dumped stone riprap. Rock in wire baskets (called gabions) or sacked concrete riprap may be used if large natural stones are not available.

Many of these erosion control measures can be accomplished readily with labor and hand tools. However, trucks will be needed if there is a considerable haul distance for stone or other material.

To prevent further deterioration erosion control work should be scheduled as soon as possible after problem areas are found. Some emergency repairs probably will be needed during the wet season. Most erosion problems will be discovered during inspection of culverts following the wet season. Preventive actions should be planned and scheduled for completion before the next wet season.

Litter Pickup

Litter along the roadsides normally will not be a major problem on rural roads in developing countries. However, it may be a desirable policy to schedule periodic cleanup of discarded trash and waste material that often accumulates along roadsides adjacent to cities and towns. Some agencies set aside an annual cleanup week. In densely populated areas, more frequent pickup may be needed.

Members of the cleanup crew are provided with large bags. They walk down each side of the road picking up trash and litter and placing it in the bags. As needed, the bags are dumped in a truck or animal-drawn cart which accompanies the crew.

In addition to these formally scheduled cleanups, all maintenance personnel should constantly watch for and pick up any large object or dead animal on the roadway surface or shoulders. Such items are hazardous to the traveling public.

BRIDGE MAINTENANCE

Bridge maintenance operations usually require some special knowledge, skills, and equipment. For this reason, many agencies establish one or more specialized bridge crews for nationwide or district-wide operation. These crews are under the overall direction and supervision of an experienced bridge engineer and are responsible for all major repairs.

Figure 47. Machine Shaping of Ditches With Motor Grader (Ghana).

Figure 48. Checking Flow Line for Low Spots (Dominican Republic).

Figure 49. Cleaning Ditches by Gradall.

Figure 50. Cutting Roadside Grass and Brush in Indonesia.

Figure 52. Riprap Down Channel (Indonesia).

Local area laborers often assist the special crews. Some less technical work can be initiated and performed solely by the local crews.

This section includes bridge maintenance activities and how they should be scheduled and performed, but only in general terms since almost all bridge maintenance requires engineering attention.

Bridge Inspection

Highway agencies should establish a record keeping system for all bridges on the road system. Recorded information should include the date of construction, type of construction, dimensions, construction plans, and the dates and descriptions of any major maintenance and repairs that are performed.

Bridge engineers at the headquarters level should be responsible for maintaining the bridge records and for conducting periodic field inspections of all bridges to evaluate their condition and identify needed repairs. A principal reason for the historical records is to assist the engineers in making these evaluations.

When there are large numbers of bridges in a system, it is difficult to conduct an engineering inspection and evaluation of all bridges each year, or even over a period of several years. For this reason, maintenance supervisors in the local areas should be responsible for an annual inspection of all bridges in their areas to (1) observe and record current conditions, (2) identify routine maintenance operations that should be performed by local crews, and (3) identify any unusual conditions that should be called to the attention of bridge engineers for technical evaluation.

To facilitate this regular inspection at the local level, a formal inspection check list should be developed and made available to the supervisor. For each item to be checked, space can be provided for checks under appropriate columns such as "Satisfactory Condition," "Needs Repair," or "Needs Engineering Study." Space also should be left for special comments by the inspector. An illustrative checklist is shown in Figure 56.

The engineers should be advised of those items needing engineering study. Copies of the checklists should be kept in the local office to guide the scheduling of bridge maintenance work.

Signing and Approaches

The following work usually can be performed by local crews with hand tools:

1. install new signs where needed — signs such as narrow

Figure 51. Brush Cutting (Ghana).

Figure 53. Grouted Riprap Down Channel (Honduras).

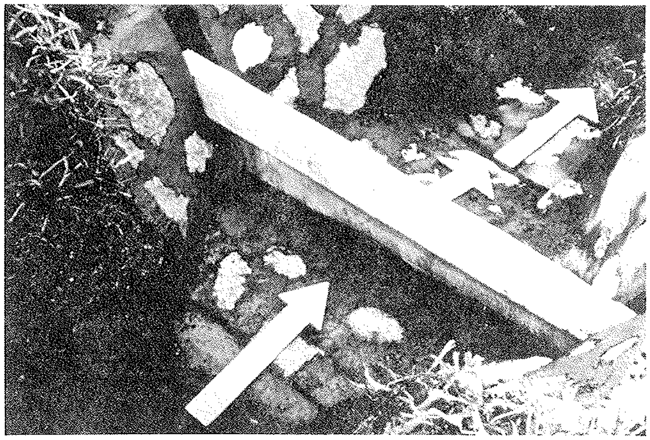


Figure 54. Ditch Check.

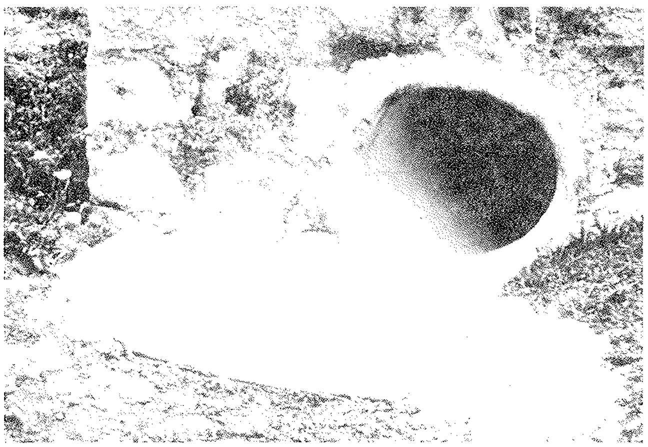


Figure 55. Culvert Outlet Apron (Honduras).

bridge, bridge speed limit, reduce speed ahead, load limits, vertical clearance, delineators leading to narrow bridge, or any other necessary signs;

2. clean and repair existing signs so that posts are straight and messages are legible;
3. remove brush, grass, weeds, and tree limbs that obscure signs; and
4. repair and paint guardrails at bridge ends.

Assistance should be obtained from bridge engineers with respect to uniform and consistent wording of sign messages and locations of signs.

Waterways

Local crews should remove debris (trees, logs, and brush) lodged in the channel or against the piers. Debris should be removed from the river bank and burned so it will not be picked up by the next high water.

Eroded areas on banks and abutments should be repaired and reinforced with stone riprap.

Any major cleaning or changing of the channel under bridges usually requires large special equipment and should be performed by special crews under direction of an engineer. Improper deepending or changing of the channel might worsen conditions of scour and erosion.

Severe scouring around piers can lead to settling and structural failure. Heavy riprap should be placed around the piers to correct the condition and prevent future scouring.

BRIDGE
PREVENTIVE MAINTENANCE CHECKLIST

BRIDGE NO. ____________ ROUTE NO. ____________ DATE ____________

STREAM ____________________ FOREMAN ____________________

ITEM	Satisfactory Condition	Needs Repair	Needs Engineering Study	COMMENTS	Date Reported
SIGNING					
Advance Warning					
Load Limit					
Delineation					
WATERWAYS				NOTE	
Debris in Stream				Use this comments column freely to indicate in more detail just what maintenance operation is needed.	
Fences			X		
Islands or Sand Bars			X		
Erosion or Scour					
Berms					
Riprap				EXAMPLES	
APPROACHES					
Steep				The upstream pile of the north pier is broken.	
Rough					
Setting or Raising				3 new deck planks needed - 3" X 12" X 24'	
SUBSTRUCTURES					
Abutments				Use the other side of this checklist as additional space for comments.	
Piers					
Piling					
Caps					
Bridge Seats				Use photos and sketches freely.	
Spalling (Abutment)			X		
Spalling (Pier)			X		
Paint					
SUPERSTRUCTURES					
Truss Broken			X		
Truss Bent			X		
Truss Rusted Out			X		
Stringers (Timber)					
Stringers (Steel)					
Steel Girders					
Concrete Girders			X		
Bearings			X		
Expansion Devices					
Expansion Joints			X		
DECKS					
Timber					
Concrete					
Steel					
Curbs					
Sidewalks					
Railings					
CLEANING					
PAINTING					

Figure 56. Illustrative Bridge Preventive Maintenance Checklist.

This may be difficult if the water is deep. Because of the seriousness of the condition, a bridge engineer should be consulted to plan and direct the work.

Substructures

Nearly all maintenance and repair operations on bridge substructures require special knowledge, tools, and equipment. The work should be planned by engineers and performed by special crews or by contractors.

Typical problems to observe and correct are as follows:

1. Spalling and deterioration of concrete, particularly at the water line, occurs on both concrete piers and piles, and can be corrected by building a form around the damaged area and pouring a properly reinforced and anchored concrete collar.
2. Cracks in concrete abutments and piers can be patched with mortar, but this may be a temporary measure. Cracks that continue to grow in size indicate a weakness, and probably will eventually require reconstruction.
3. Damaged piles can be cut off below the point of damage and new sections of pile spliced to the stub, or new piles may be driven adjacent to the broken pile.
4. Damaged steel pilings can be repaired by cutting out the damaged section and welding in a new section.
5. Damaged or broken timber pile caps can be spliced, and broken sway braces on timber piles can be replaced.

Local area maintenance supervisors should watch for signs of these problems and should call for engineering assistance in making the repairs.

Superstructures

The superstructures of truss bridges can sometimes be repaired by replacing damaged members or by strengthening weakened members with welded steel plates. This should be attempted only with engineering planning and direction.

Damaged timber beams may be repaired with U-bolts placed around the beam and up through the deck, or new beams may be fastened alongside the damaged beam.

Steel beams are seldom replaced. Repairs usually can be made by welding plates to damage areas. Spalled or broken areas on concrete beams should be cleaned and patched with carefully designed and proportioned mortar or shotcrete.

Decks

Because little special technical knowledge and experience is needed in many cases, maintenance and repair work on bridge decks can be performed by local area crews. Some special tools and materials must be available to the crews. If not, the work should be scheduled for specially equipped bridge crews.

Timber decks are easily repaired by replacing broken, worn, or decayed planks (Figures 57, 58 and 59). Spalled areas in concrete decks may be repaired by cutting out all damaged material, cleaning exposed reinforcing steel and filling the hole with concrete. Reinforcing steel should not be cut or damaged.

Broken or decayed timber curbs should be replaced. Deteriorated concrete curbs can be repaired by removing unsound material, treating with cement grout slurry, and replacement of concrete.

Timber railings should be of sound material, firmly fastened. Figure 60 shows a bridge rail in need of repair. Repairs may require new posts and railing planks. Missing bolts and nuts should be replaced. Untreated timber posts and rails should be painted.

Concrete railings are repaired in the same manner as the deck and curbs. Steel railings should be kept painted to protect against corrosion.

Figure 58. Deck Repairs Underway (Sierra Leone).

Cleaning and Painting

Concrete and timber structures normally are not painted except for the painting of curbs, railings, and railposts.

Steel structures are painted primarily to protect the metal against corrosion. Some safety benefits are derived through improved visibility when light colored paints are used. The frequency of needed painting depends on the type of structure, climatic conditions, and the quality of the paint.

Careful cleaning of the structure is an essential first step. Dirt, rust, scale, chalky paint pigment, and other foreign materials must be removed. A high pressure water or compressed air jet is helpful, followed by cleaning with hand scrapers and chippers or with sandblasting equipment. Primer paint should be used on bare metal spots. Paint may be applied either by brush or spray.

Because of the special equipment used, cleaning and painting should be performed by a special bridge maintenance crew.

TRAFFIC SERVICE MAINTENANCE

Traffic service maintenance generally is considered to include items related to signs, traffic signals, pavement markings, and street lights, i.e., the roadway items that exist principally for the safety and convenience of motorists. The follow-

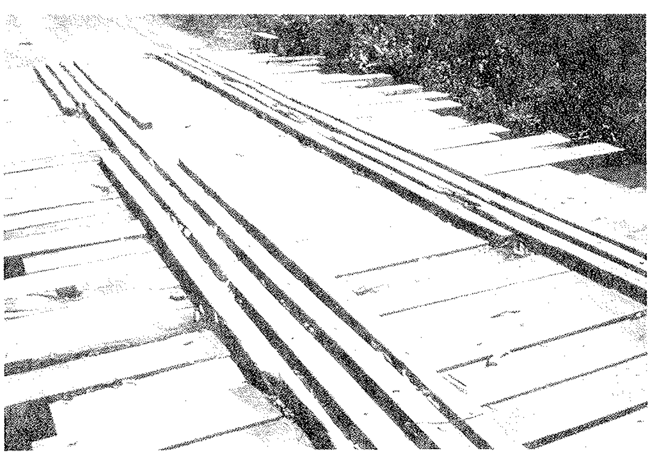


Figure 57. Deteriorated Timber Bridge Deck (Sierra Leone).

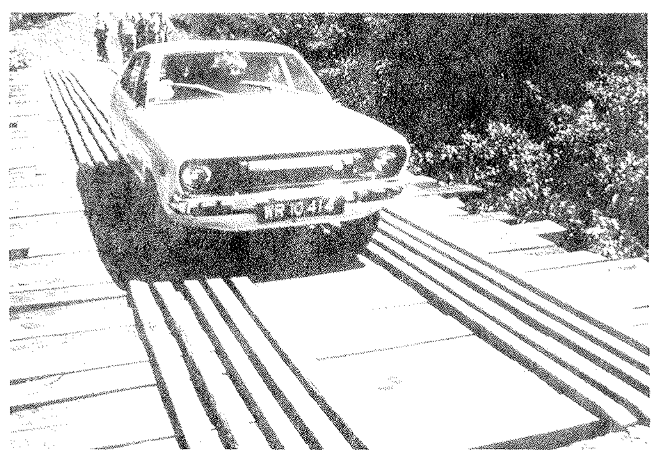


Figure 59. Completed Bridge Deck Repair (Sierra Leone).

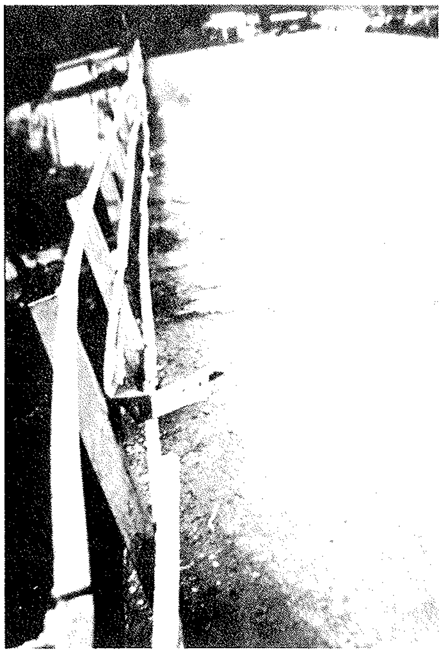


Figure 60. Bridge Rail in Need of Repair.

ing discussion is limited to maintenance and repair of signs since that appears to be the only traffic service function that is associated with rural unpaved roads.

There are several categories of signs:

1. *warning signs* for curves, narrow bridge, do not pass, railroad crossing, etc.;
2. *regulatory signs* for speed limits, load limits, stop, and yield; and
3. *information signs* for directions and distances.

It is important that these signs be properly placed and maintained in good condition. Sometimes the signing is designed and placed as a part of road construction contracts. Sometimes the signs are purchased or manufactured by the highway agency and installed by maintenance forces. In any case, a highway agency needs to have a readily available source of posts and sign faces for repair and replacement of damaged signs, either from their own sign shop or from a commercial supplier.

Overall policies for standard signs and their placement should be established at the headquarters level to assure nationwide consistency. International standards have been developed to guide individual agencies. Reference should be made to those standards to insure uniformity.

Sign Maintenance Operations

Conditions that bring about the need for sign maintenance are described below, together with a discussion of the work to be performed.

Signs do little good unless they can readily be seen by motorists. Growth of tree limbs, brush, and weeds sometimes blocks the view of signs. Visibility should be checked periodically, and any vegetation in the way of signs should be trimmed.

Signs often get dirty from dust and mud. A regular program should be established for periodically washing the signs with water. After a time the paint may scale off or deteriorate so that the message is no longer clearly legible. These sign faces should be repainted or replaced.

Signs and sign posts may be damaged as a result of accidents, and wood signs and posts are susceptible to rotting. Maintenance supervisors should watch for these conditions and should repair or replace the signs as soon as possible.

If conditions change, signs may be needed where none currently exist. For example, a new intersection may be constructed and stop signs may be needed; or accidents may show a hazardous location where special warning signs should be installed. Headquarters or district-level traffic engineers normally should authorize these installations by special sign crews or local area maintenance forces.

Traffic Safety in Work Areas

One other important traffic service operation is to assure the safety of both motorists and maintenance crews during work operations on the road. Traffic is a hazard to the maintenance crew, and road repairs and maintenance equipment can be hazardous for motorists. The danger increases with higher traffic volumes and traffic speeds.

The first step in every maintenance performance standard should be a provision for setting out appropriate traffic safety devices such as

1. advance warning signs that are placed about 400 meters ahead of the work area with messages such as "Reduce Speed — Road Repairs Ahead;"
2. follow up warning signs placed about 100 meters ahead of the work site;
3. barricades to separate the crew and equipment from traffic or to divert motorists away from excavated areas; and
4. flagmen to direct and control traffic each side of the work site.

Signs must be located where they are readily seen by drivers, i.e., about 1.5 meters above the roadway and at least 0.5 meter outside of the roadway shoulder. They should be located just ahead of, not just beyond, a blind curve or crest of a hill. For moving operations, the signs should be moved occasionally as the crew moves along the road. When work is not completed during the day, warning lights should be provided at night to protect motorists from excavations or piles of material.

Warning signs should always be removed when they are not needed. When motorists frequently see warning signs with no work underway, there is a gradual tendency to ignore the signs in the future.

REHABILITATION AND BETTERMENT

As mentioned in Chapter II, rehabilitation and betterment works are not generally considered to be maintenance operations. They might better be identified as minor construction. But quite often the work is performed by regular maintenance crews and financed with maintenance funds. Normally, the planning, scheduling, and financing of this work are necessary parts of the total maintenance program.

Purpose

When maintenance has been neglected for a considerable period of time, road sections may deteriorate so extensively that normal maintenance operations cannot adequately improve the level of service. Rehabilitation is for the purpose of restoring these sections to their original condition as constructed, and usually includes work on all elements of the roadway including surfacing, drainage, ditches, and slopes.

Betterment work is for improving some or all elements of a road section to standards higher than the original construction. The work might extend throughout long sections of road or be limited to isolated spot locations. Betterments often are needed on roads where traffic volumes have increased significantly since the road was constructed, or where the original design was inadequate. Betterments are a form of stage construction and are discussed more fully in Synthesis 2, *Stage Construction*, to be published in 1979 by the Transportation Research Board.

Planning

Rehabilitation and betterment works should be identified as individual special projects. Potential projects are listed during the annual inventory and evaluation of the road system. Priorities are established based on the estimated costs and benefits of specific improvements.

After projects have been selected for an annual work program, decisions must be made on which projects can be performed by maintenance forces and which projects should be let to contractors. In either case, some simple plans are prepared to show clearly the limits of the projects, typical roadway cross section, surfacing materials, drainage features, and any changes in vertical grade elevations and horizontal alignment. Quantities of work items and materials should be estimated and cost estimates prepared in the same manner as for a construction project.

When rehabilitation and maintenance work is to be a continuing regular part of the annual work programs, agencies should establish one or more special crews that are staffed and equipped for these more extensive operations. Because the work resembles construction more than maintenance, the desirable equipment includes units such as trucks, front-end loaders, motor graders, bulldozers, heavy rollers, and even large scrapers if there is a considerable amount of earth to be moved.

If private contractors are available, an agency may find it more economical to perform improvement work by contract rather than with its own work force and equipment. Owning, operating, and maintaining large units of specialized equipment becomes quite expensive if the utilization rate is not consistently high throughout the entire year.

Some small improvement projects such as new or upgraded pipe culverts and drainage ditches can be accomplished effectively with labor and hand tools. It is extremely difficult to undertake projects involving large quantities of roadway earthwork and surfacing materials without some degree of equipment utilization.

Types of Improvements

Some of the types of improvements that should be considered to supplement the regular maintenance program are as follows:

1. *Roadway widening.* Some road sections, originally constructed or developed as one-lane roads, may now have traffic volumes to justify two-lane traffic for safety and convenience. Earthwork is required for widening the roadbed and constructing new roadside ditches. Drainage culverts must be lengthened. New surfacing material must be placed on the widened shoulders. Usually, it is a good idea to resurface the entire roadway width as a part of this operation.
2. *Grade elevations.* Roadway surface elevations should generally be at least one-half meter above the adjacent terrain in order to assure adequate drainage and a stable subgrade. The roadbed should be elevated on those sections that were constructed too low or that have gradually eroded below the natural ground elevation. The work involves importing materials or widening the roadside ditches to obtain material for raising the roadbed.
3. *Curve flattening.* Some road sections with generally acceptable alignment may have several very sharp curves which are hazardous and which slow the traffic movement. Improvements can be made by reconstructing these short segments with a flatter degree of curvature.
4. *Sight distances.* Unsafe sight distances often occur at the crest of very sharp vertical curves. Safety improvements can be made by lowering the elevation at the crest and using the excavated material to raise roadway embankments on either side of the crest.
5. *Drainage.* Severe drainage problems may be attributed to lack of culverts at essential locations or existing culverts that are too small. Improvement projects should include raising the roadbed level, installing new culverts, and replacing inadequate culverts along with construction of the necessary inlet and outlet ditches.
6. *Surface improvements.* Existing earth surfaces might be improved with a carefully graded and stabilized crushed gravel surface. Existing gravel surfaces may be upgraded with a bituminous surface treatment where traffic volumes have increased significantly.
7. *Bridge widening.* Narrow bridges present a serious hazard, particularly one-lane bridges connecting with two-lane road sections of principal highways with considerable traffic volume. Widening of these structures can be an important part of the improvement program.

The types of rehabilitation and betterment works discussed are not maintenance. Neither can they be considered totally new construction projects. However, these operations provide a realistic and economical approach to improvement of service levels beyond the capabilities of normal maintenance.

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