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Foreword

Roads often bring significant economic and social benefits, but they can also have substantial negative impacts on communities and the natural environment. As we become more aware of these impacts, there is a growing demand for the techniques and skills needed to incorporate environmental considerations into road planning and management.

This handbook is the result of a joint effort of the World Bank and SETRA (Service d'Etudes Techniques des Routes et Auto-routes), the technical arm of the French Ministry in charge of Infrastructure and Transport. It is aimed primarily towards:

- **Road agency managers**, who need to broaden the skills and capabilities of their organizations to deal with new issues such as the natural environment, social impact analysis, community consultation, landscape design, and environmental law.
- **Road engineers, planners and contractors**, who need to increase their awareness of environmental issues at all stages of their day-to-day work.
- **Environmental specialists, community groups, academics, development organizations** and others with an interest in the relationship between roads and the environment.

A key objective of the handbook is to integrate environmental thinking into road planning and management, and to improve communication between different disciplines and interest groups, which often use different concepts and terminology. Engineers, for example, need to know when to call in experts, what terms of reference to give them, how to integrate their advice into other road management activities, and how to implement and follow up on environmental strategies.

The handbook is being released at this time as an interim working document, which will be updated and revised in the light of user experience. Readers are encouraged to use the handbook in studies and training, and to use it as a basis for developing national guidelines more specifically related to local needs. Any comments, examples and suggestions arising from this experience will be most welcome for future revision of the handbook.

The guidelines in this handbook are not official standards for World Bank projects, but are general indications of good practice to assist road agencies in dealing with environmental issues.

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Road projects are generally undertaken to improve the economic and social welfare of those using the road or served by it. Increased road capacity and improved pavements can reduce travel times and lower the costs of vehicle use. Benefits include increased access to markets, jobs, education and health services, and reduced transport costs for both freight and passengers.

For all the positive aspects of road projects, they may also have significant negative impacts on nearby communities and the natural environment. People and properties may be in the direct path of road works and affected in a major way. People may also be indirectly affected by the project, through the disruption of livelihood, loss of accustomed travel paths and community linkages, increases in noise and pollution, and more road accidents. Disturbances to the natural environment may include soil erosion, changes to streams and underground water, and interference with animal and plant life. New roads may bring development into previously undeveloped areas, sometimes causing significant effects on sensitive environments and the lifestyles of indigenous people. Roads bring people, and people bring development. Roads are agents of change, which can bring both benefits and damage to the existing balance between people and their environment.

All of these concerns will rarely arise within a single project, but it is common to find at least some even in relatively minor road works. Much can be done to avoid, mitigate, or compensate for the negative environmental impacts of a road project. It is important to identify potential impacts early in the road planning process and to make provision for avoiding or mitigating these effects wherever possible. Failure to identify potential impacts may result in delays and cost increases later in the project. Neglecting to account for impacts may also cause the road agency to adopt unsatisfactory compromise solutions to environmental problems. Poor environmental management has been shown to produce negative public perception of road projects, creating additional problems for future road projects.

Roads can harmonize with the surrounding environment and serve multiple users.
A truly sustainable approach to road transport development calls for a substantial change of thinking towards the environment in the preparation and management of road projects. Indirect costs of pollution and disruption must be costed. Changes to the social, health and cultural well-being of communities, and impacts on the natural environment and biodiversity, must be considered. The needs of the poor, and of future generations, need to be taken into account.

This change has three elements. First, the full range of impacts on the natural and social environment need to be identified. Second, these impacts need to be quantified. The techniques for this analysis are often substantially different from those used in road engineering, and are often less well developed. In some cases, like the health effects of motor vehicle air pollution, scientific consensus is still only gradually emerging. Third, procedures need to be established for avoiding, mitigating and compensating for these impacts. These should include provision for consulting with affected communities, following up with implementation plans, and training.

This handbook is primarily concerned with specific road projects, ranging from major works on new alignments to minor rehabilitation and maintenance activities on existing roads. The techniques discussed can be applied to in-depth environmental assessment studies, or to modest action plans for dealing with environmental aspects of small projects.

The handbook does not deal in any detail with alternatives to motorized transportation, including measures to restrict demand for motor vehicle use, expansion of public transport services, support for non-motorized modes of travel, and long-term changes in urban form and travel patterns. These issues are critically important for the establishment of sustainable transport services, and should be fully considered in the analysis of transport strategies and large urban road projects. While they are discussed briefly in various chapters of this handbook, they are largely outside the scope of this document, and need to be more fully dealt with elsewhere.

**Part I. Environmental assessment processes**

This handbook begins with a discussion of the processes commonly used to take account of environmental issues for roads. The term environmental assessment is used to describe a rigorous analysis of impacts of road improvement alternatives. A more limited study or action plan for dealing with specific impacts is known as a mitigation plan or environmental management plan. A process of screening is used to identify the potential magnitude of impacts and depth of study required, while scoping considers the range of impacts, affected land area and time scale of impacts, and hence the limits or range of environmental factors to be studied. These processes may be applied to a specific road project, or to a broader consideration of road, transport, and environmental strategies at a regional or national level. This handbook concentrates primarily on project-level analyses, but some of the techniques and approaches can also be used for strategic environmental studies.

Part I describes the main components of a typical environmental assessment study and how the assessment should be integrated into
the project cycle. Guidelines are provided for overall study definition, including requirements for baseline studies, impact analysis, mitigation options and costing, and plans for implementation, monitoring, and evaluation of specific actions.

Community consultation and participation
Communities affected by road projects have a substantial interest in decisions made in planning and design, and can often assist with information on local conditions and preferred mitigation measures. Timely consultation and participation are very important, and can take many forms, as discussed in chapter 4, but skilled staff and careful planning are needed to ensure good results.

Environmental staffing, skills and training in road agencies
For all these actions to be effective in practice, road administrations need to assure appropriate implementation and supervision by trained staff. Information is provided in chapter 5 on administrative arrangements for environmental assessment and management in road projects, including the staffing of environmental teams, training programs, contract clauses and supervision, and regulatory issues.

Ultimately, road agency staff at all levels are responsible for the road environment experienced by motorists, other road users and roadside neighborhoods. In addition to serving the needs of motorized traffic, they must become the caretakers of community values and the natural environment, and to some extent representatives of the poor and of future generations.

Part II. Environmental impacts and mitigation measures
Part II discusses specific impacts and mitigation measures in some detail, with emphasis on:
- The natural environment, including soil, water, air, plant and animal life (chapters 7–10)
- The human and social environment, including community life and economic activities, land acquisition and resettlement, traditional or indigenous peoples, landscape, cultural heritage, noise and road safety (chapters 11–17).

The first step in assessing each of these environmental aspects is to identify potential impacts and problems. Avoidance, mitigation, or compensation measures are then suggested. The key points and an environmental
checklist are presented for each section to highlight the problems which are most likely to be encountered in the particular environment. Guidelines for actions to be taken by the road agency to avoid problems in each environment are then suggested with advice on items for terms of reference for further studies.

A road project may provide opportunities for positive environmental impact. The handbook includes examples of features incorporated into projects to have a positive effect on the environment, such as reestablishing local vegetation, improving water flows, and protecting sensitive sites.

Managing road works and traffic operations
A discussion of the potential environmental impacts of different types of road projects, including construction, rehabilitation, and maintenance, is also included in chapters 18–20. Definition of the responsibilities of road agency staff in sensitive environments, responsibilities of contractors in activities such as quarrying, earthworks, planting, traffic management, and road safety, and potential contract clauses and suggested provisions for remedial measures are included here.

Part III. Analysis Tools
Chapters 21–23 provide details of some technologies and methodologies which may be useful in the assessment of the environmental impacts of a road project, including sections on maps, aerial photography, computer programs, training, and public involvement.

A bibliography is provided after each chapter, and at the end of the handbook, with references in various languages.

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**Key recommendations for road directors**

1. Road agencies should have a clearly-defined staff member with overall responsibility for environmental matters, and knowledge of environmental laws and regulations.
2. The environmental coordinator should have access to senior management, and their support in coordinating environmental actions throughout the organization.
3. Identification and assessment of potential environmental impacts should be an integral part of the project cycle. It should commence early in the planning process to enable a full consideration of alternatives, and to avoid later delays and complications.
4. Assessments should be followed up with action plans, monitoring and remedial measures to ensure the effectiveness of environmental recommendations and decisions.
5. Road agencies should develop global policies, procedures and standard contract clauses for the consideration of environmental factors; these should apply to road strategies, planning, management and operation.
6. Road agencies should review environmental aspects of laws and regulations related to road planning, road works and road use, and make recommendations to other government agencies and departments on the need for improvements to the legal framework.
7. Community involvement is an essential element of environmental management of roads. Procedures and skills should be developed for informing the public and interested parties about road proposals, and using consultation and participation to include the community in the decision-making process. This process recognizes the importance of non-technical factors in assessment of environmental issues, and the problems experienced in many road projects through a lack of timely consultation.
8. Training is required for road agency staff, consultants and contractors responsible for assessment of environmental impacts and mitigation measures, and implementation and monitoring of action plans.
Part I

The environmental assessment process
Assessing the environmental impact of road projects

KEY POINTS

- Environmental assessment of a road project should not be seen as a single activity at one point in time, but as an ongoing process which is integrated with the project cycle of planning, design, construction, and operations.

- A comprehensive assessment typically covers documentation of existing conditions, identification of impacts, and examination of alternatives. More limited environmental assessments usually focus primarily on mitigation measures.

- Strategic environmental assessments are also used in the development of broader policy and guideline reports which apply beyond the scope of an individual project. While these are not the main focus of this handbook, many of the techniques presented here could also be used for these purposes.

KEY WORDS: Project cycle, screening, scoping, mitigation plan, physical and natural environment, human and social environment, strategic environmental assessment
Roads and the environment

There is growing awareness of some of the major environmental impacts of large road projects, such as their effects on sensitive natural environments, or resettlement of large numbers of people. These cases usually call for large-scale environmental assessment studies, carried out by specialist teams. Substantial time and effort is often required to fully identify impacts and options, consult with various groups who have an interest in the project, develop mitigation plans, and implement the results. In these cases, road agencies need to understand the assessment process and coordinate it with road planning, design and construction activities, allowing sufficient lead time and funds for the additional steps which arise from this process.

Smaller environmental issues arise frequently in road rehabilitation, maintenance, minor construction projects, and traffic management and regulation. These situations do not call for major studies, but environmental awareness and procedures need to be in place.

Contract clauses, work procedures and staff training need to be prepared, and work processes need to give greater attention to roadside communities, flora, and fauna. Road agency staff need to be able to recognize potential environmental concerns. They should know when to call in specialist experts, how to specify and manage their work, and how to implement the results.

These issues call for an increased ability to communicate and consult with affected residents and interested members of the public, government departments, and other organizations. While road agencies are generally quite responsive to concerns of these groups on technical issues, the dialogue on environmental issues needs to be expanded to include a broader range of issues, some of which are more difficult to quantify and define. This requires new skills and procedures, which have to be developed to meet the needs of different countries and cultures.

Road developments also affect the long-term growth of transport demand, which can have major impacts on the environment in densely populated areas. Unconstrained growth of road traffic leads to environmentally unpleasant congestion, pollution and noise in large urban areas, and is not sustainable in the long term. The only way out of this cycle is to plan for more efficient use of transport modes, and environmental analysis in these cases must therefore consider alternative future scenarios for demand growth, and the effect of infrastructure projects as a component of these scenarios.

Environmental assessment at the project level

Conducting a study of the natural and social environment in which a road project is to be developed requires more than an understanding of the technical procedures involved in road construction. It also requires knowledge of the appropriate procedures for studying the environment and the ability to meaningfully analyze the data that is collected. The process that has evolved to obtain the desired environmental information is known as environmental assessment. Performing an environmental assessment prior to beginning construction is important for the road agency, because it will allow them to foresee any environmental considerations that may affect the road project. The environmental assessment will avoid costly construction delays, will allow the agency to better integrate the project into the existing environment, and
will familiarize the agency with the environmental status of the proposed site. Increasingly, the environmental assessment is required by national and international law or enforced by other regulations. Therefore, the environmental assessment should be considered and provided for in the budget of the road project from the outset.

In this handbook, a full environmental assessment (or environmental impact statement) is conceived as a rigorous study that involves a thorough documentation of existing conditions, identification of impacts, and examination of alternatives for the road project. It may not necessarily cover all of the land areas affected by the project or all environmental factors. These issues should be resolved in the scoping process.

In many cases a more limited environmental analysis is appropriate. This type of study would principally focus on specific impacts and their mitigation. The result of this type of study can take a variety of forms, but are sometimes presented as a self-standing mitigation plan or an environmental management plan.

From an engineering or planning perspective, project development generally follows a well-defined cycle which includes preliminary and feasibility studies, preliminary design, detailed design, and construction, followed by operation and maintenance of the completed project. Depending on the nature of the project, consultation with various government agencies or the public, or both, may be an important component in several of the early stages of this cycle.

The process of environmental assessment for road projects also consists of a number of distinct steps, including screening and scoping of studies required, environmental assessment studies, mitigation plans, training, and monitoring. Consultation is also frequently needed at several points in this process. It is important to synchronize environmental studies with the project development process and its technical studies, in order to integrate findings into planning, design, and further analyses as early as possible, and achieve the best results from both types of activity.

Table 1.1 shows the approximate stages of the project cycle at which environmental assessment actions typically occur. For comparison, typical stages of the project financing

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Note: The table shows comparative timings which are indicative and not necessarily fixed for all cases.
cycle are also shown, from the perspective of a lending institution.

Each of the steps in the environmental assessment process should have a well-defined output. The screening and scoping stage should produce a preliminary evaluation of the magnitude of potential impacts, and hence the need for further study. Screening is generally used to decide whether the project requires a formal environmental impact study, or some lesser level of analysis. Scoping is the process of defining the limits of impacts, land areas, and time scales which need to be investigated. The environmental assessment report is the most visible output. Its function is to provide decisionmakers with information regarding the environmental issues, impacts, and mitigation options for a particular project or road program. This assessment should then be used in an integrated evaluation of project options and consequences, taking account of costs (construction and maintenance), access and transport objectives (transport efficiency, safety, economic development), and impacts on the natural and social environment.

When potential negative environmental impacts are identified, measures can be taken to avoid the impact, mitigate (or reduce) its effects, or compensate for the effects either financially or through offsetting positive actions. In this handbook, these approaches are sometimes collectively referred to as mitigation measures.

**Environmental assessment at the program level**

There are a number of ways in which environmental assessments can be used to take account of issues which are broader than those of an individual project. These are sometimes known as strategic (or sectoral) environmental assessments (SEAs), and can be applied in several ways:

- To develop generalized environmental guidelines for projects which might not otherwise warrant specific environmental assessments. This does not require the accumulation of data for all sites, but uses existing information to develop mitigation guidelines for avoiding or limiting adverse environmental impacts, and compensation principles for dealing with environmental damage. These can be used to develop mitigation plans for specific projects or groups of projects. When deciding whether to use a site-specific environmental assessment or general environmental guidelines developed from a strategic assessment, the road agency should consider the environment of the proposed site, all environmental policies governing the site, and the type of development planned.
- To take account of environmental factors in the development of transportation strategy plans, which may be at a national, regional, or local level, and may deal with roads only, or with intermodal transport issues. The environmental contribution to such plans should review the development objectives of the region, the relationship between develop-

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**BOX 1.1**

**Coordination of transport and land-use planning**

Coordination of road and transport planning with land use planning is a way to limit adverse environmental impacts, avoid conflicts, and achieve efficient and environmentally adapted transport systems. It can be used to assess and regulate potential secondary development along road corridors, especially in sensitive regions and near areas of land reserved for conservation purposes.

Land-use planning issues are usually considered as an element of project planning, and included in project environmental assessments. However only a few countries have developed land-use plans and policies for use at national and regional levels, i.e., outside urban areas. Regional comprehensive land-use plans, where they exist, provide an important information base for road environmental studies. Conversely, a road or transport planning issue can sometimes be a catalyst for initiating a comprehensive land use plan for the region concerned.

*Source: OECD 1994.*
ment and the environment, and the effect of various transport alternatives on economic and social development and the natural and human environments. Conversely, sectoral environmental analysis can be used to incorporate roads and transport issues into broader national or regional environmental action plans.

* To develop environmental concepts and strategies in the transportation planning process. This involves a deeper review of the role of roads and transportation in development, the measurement and control of transport impacts on the environment, and the promotion of a balanced and sustainable mix of transport alternatives which best meets both development and environmental objectives. This requires an analysis not only of infrastructure but also of land use (see box 1.1), road user charges, emissions legislation, and other policies which can influence transport choices.

Broad transport sector policies and strategies clearly have significant impacts on the environment which require detailed consideration. However, this is a substantial topic in its own right and goes beyond the scope of this handbook, which focuses primarily on the assessment and management of environmental impacts of specific road projects.

**Project timeline and budget**

Among the factors to be considered before beginning the environmental assessment are the time to be devoted to the study and the budget for preparing the study. While it is difficult to suggest exact financial and temporal guidelines governing the environmental assessment, the duration of an environmental assessment is usually from six to eighteen months. Experience has shown that the earlier the environmental assessment is conducted in the project cycle, the more quickly and cost-effectively it is completed. An environmental assessment begun late in the project cycle may cause delays to the project.

Expenses for a full environmental assessment have been found to be within 5 to 10 percent of project preparation costs. The budget and timeline expenditures for less-extensive environmental analyses are well below these levels; studies as brief as six weeks have been reported. The cost of mitigation actions are better documented; an allocation of 2 to 5 percent of project construction costs is often required, and could be higher in urban areas or sensitive locations.

Questions that should be considered when determining the project timeline and budget are:

* Is information available in existing databases or is a field study necessary?
* Should the study be conducted by an external project team because of the environmental expertise required, or can it be done in-house by a generalist?
* Is the study parallel with technical and economic investigations, or is a report requested only after such planning work has been completed? The latter is often more expensive, has tighter time constraints, and can lead to delays in the project.

**Bibliography**


Environmental assessment procedures

KEY POINTS

- Screening is used to determine the depth of environmental study required. From an examination of the project scale and type, magnitude of likely impacts, and sensitivity of the project location, it establishes the need for a formal environmental assessment report, or for some lesser degree of study, or no study at all.

- Scoping determines the limits of an environmental assessment study, in terms of the area covered, impacts considered, and time frame evaluated.

- Typical contents of a full environmental assessment report are described, including project description, baseline data, impact predictions, analysis of alternatives, mitigation plan, and training and monitoring arrangements.

- More limited environmental assessment studies may be appropriate where expected impacts are limited. These often take the form of a self-standing mitigation plan, with emphasis on the practical steps required to avoid, mitigate, or compensate for the environmental impacts identified.

- Consultation with affected groups, and other interested organizations, individuals, and government agencies, is often an important component of these studies.

KEY WORDS: Screening, scoping, baseline, impact, mitigation, monitoring, consultation
Screening
Screening is the term used to describe an assessment of the potential magnitude of impacts and hence the depth of study required. This should be the first stage in incorporating environmental considerations into a road development project. While the methods used by various agencies vary in their details, projects are generally classified according to the degree of environmental information needed, into one of three categories: (a) full environmental assessment (also known as an environmental impact statement), (b) limited environmental analysis or mitigation plan, and (c) no environmental study.

Sometimes there are precise regulations as to which study should be applied to a project. In cases where legal or regulatory guidelines governing the environment do not exist, it may useful for the agency to draft guidelines. These will ensure that the environmental studies are approached systematically and consistently. In other cases the degree of study needed will be at the discretion of the agency. In these instances, the factors that should be considered are:

• Scale and type of project
• Location and sensitivity of the site
• Nature and magnitude of potential impacts. These factors are discussed in more detail in the following sections.

Scale and type of project
The scale and type of road work can vary between major projects such as a new highway of hundreds of kilometers, and minor projects like the maintenance of a few kilometers of rural road. Some regions have regulations that determine the degree of environmental assessment required based upon the type and scale of the project. In this situation a program for a new expressway might require a full-scale environmental assessment whereas the maintenance work might require no assessment. There are many intermediate situations and other factors to be considered in selecting the extent and type of environmental study required.

Road classification systems vary between countries, but generally subdivide roads by function (interstate highway, arterial, distributor, local access) and by jurisdiction (national, provincial, municipal). The engineering standard of these road classes varies substantially between countries and regions.

Road projects can also take a variety of forms. From the point of view of environmental impacts, the major categories are:

• New construction: A new road built on a new alignment, generally with some options available in the choice of route and design standard.
• Realignment: Upgrading and changes in the alignment (route) and grading of an existing road.
• Rehabilitation and widening: Actions include strengthening pavements, widening lanes and shoulders, adding lanes, and improving drainage.
• Maintenance: Routine works include patching potholes, clearing drains, and mowing grass while periodic works are required for resurfacing, linemarking, bridge maintenance, and other tasks.
• Traffic management: Works aimed at improving traffic flow efficiency and safety include intersection layout, signs and signals, footpaths and pedestrian crossings, provision for other nonmotorized traffic, and control of roadside access and activity.1

For a six- to seven-meter-wide pavement, the right of way typically varies between 10 and 40 meters, occupying one to four hectares per kilometer. For example, large rights of way are often found in humid tropical forests, where it is necessary to clear a wide strip to allow the pavement to dry.

Site location and sensitivity
Since the significance of potential environmental impact is often a function of the natural and sociocultural settings, the location sensitivity is one of the main factors in determining whether a full environmental assessment is needed. Sensitive locations that might warrant a full, in-depth environmental assessment include:

1. Definitions of road terms can be found in PIARC “Lexicon of Road and Traffic Engineering” (1991).
• National parks, reserves, wetlands, tropical forests, and special habitats
• Paths of migratory wildlife
• Archaeological or historic sites, or near existing cultural and social institutions
• Densely populated areas with potential noise, air pollution and resettlement issues
• Regions with large development activities or conflicts in natural resource allocation
• Airsheds with meteorological conditions potentially adding to unhealthy air quality
• Watercourses in aquifer recharge or reservoir catchment areas used for drinking water
• Lands and waters containing valuable resources such as prime agricultural soils
• Areas with unstable slopes
• Areas inhabited by indigenous peoples or other vulnerable minorities
• Areas which might require involuntary displacement and resettlement of significant numbers of people or businesses.

Nature and magnitude of potential environmental impacts
The nature of environmental impact can involve:
• Inability to provide mitigation or compensation
• Risk to human health and safety
• Cumulative effect of the proposed road project and other planned or ongoing activities
• Secondary or indirect effects.

The magnitude of impacts can be measured by:
• Absolute amount of resource or ecosystem affected
• Amount affected relative to the existing stock of the resource or ecosystem
• Intensity of the impact (if it can be quantified)
• Timing or duration of the impact
• Probability of occurrence.

Indirect effects induced by a road project should be taken into account, as they can have greater influence than direct effects. New access roads, for example, can facilitate the entry of settlers and new economic activities into previously relatively unoccupied areas, straining the existing socioeconomic and natural environments. In the case of the Polonoroeste road-paving project in the Amazon, road improvements made a remote area more accessible, and contributed to an influx of settlers with significant effects on the tropical forest, natural resources, and the indigenous peoples.

Scoping: Identifying the study area and contents
The aim of this element of the preliminary evaluation is to define the focus of the environmental assessment studies, including what can and cannot be accomplished. Definition of the scope of the study will enable concentration on the most important environmental impact of the road project. This stage should realize the following objectives:
• Define the spatial limits of the study.
• Define the time factors to be considered in the study and impact analysis.
• Select methods and parameters to be used.
• Consult with interested organizations and the affected population to identify environmental concerns.
• Define the time, skills, and manpower required for the environmental study.

Study area
The geographic area subject to potential environmental impact by the project should be clearly defined prior to beginning an environmental study. The following physical ele-
ments should be considered: the road itself, and possible alternative routes; areas indirectly affected, such as feeder roads, maintenance areas, and railways; and locations affected by construction activities, such as quarries, borrow pits, dumps, traffic diversions, work camps, and temporary accesses.

In addition, the study area should be enlarged where there is potential for environmental impacts well beyond the immediate physical surroundings. Criteria to be considered here include:

- **Ecological diversity of the site.** As this increases, the study area should be more extensive.
- **Type and scale of the development scheme.** In general, the greater the change from existing conditions, the greater the potential impact.
- **The sensitivity of the proposed surroundings,** such as natural reserves with rare wildlife.

**Time requirements for the environmental study**

These depend upon whether:

- The studies require investigation during special periods of the year (seasonal aspect of the environmental impacts).
- The fields to be studied are numerous and the results must be integrated.
- The required information is available for existing sources, such as government agencies, or will involve considerable site investigation work.

**Study methods and parameters**

Methods of study may require definition by experts with specific skills, for example in social sciences, biology, or hydrology, although less sophisticated methods can be used in some cases.

The environmental studies should not use techniques that:

- Collect or integrate data of little use to the road project and its environmental impact.
- Prolong the time needed for feasibility studies.
- Increase the cost of the project unduly.

Identifying issues and data of primary importance for the environmental assessment is one of the main objectives of this handbook. For each type of potential impact discussed in part II, the discussion of impact identification and assessment includes advice which can help to focus on key issues. In Canada, specific methods have been developed to identify valued ecosystem components, both for the natural environment and the affected communities, to assist in planning environmental studies.

**Consultation**

Methods and techniques for consultation are discussed in some detail in chapter 4. In establishing the scope of the study it is highly desirable for the different parties concerned to arrive at a consensus. Involvement of interested parties such as ministries, project designers, local officials, associations, community representatives, and local residents can help to ensure that the program will not be subject to last minute dispute. Meetings and discussions on the scope of environmental study should:

- Provide information on the objectives of the project and the alternatives under consideration.
- Identify the natural, economic, and social resources of importance in the area.
- Determine the ramifications of the project on the natural and social environment.
- Agree on the issues which should take precedence in the study.

**The environmental assessment report**

The contents of a full environmental assessment report (or environmental impact statement) should be in concordance with the main environmental issues, just as the level of detail and the report's breadth should be commensurate with the potential environmental impact. The environmental assessment report for a specific project should include the following items:

- **Executive summary:** Concise summary for decisionmakers, providing significant findings and recommended actions.

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2. Those with an asterisk [*] are not essential under all environmental processes.
• Policy, legal, and administrative framework: Presentation of the policy, legal, and administrative framework within which the environmental assessment is prepared. The environmental requirements of any co-financiers should be identified.

• Project description: Concise description of the works to be carried out, including any off-site works such as construction camps, access roads, borrow pits, quarries, or asphalt plants.

• Baseline data: Assessment of the dimensions of the study area and description of relevant physical, biological, and socioeconomic conditions, including changes anticipated before the project commences, and expected trends if the project did not take place. Current and proposed development activities within the project area (but not directly connected to the project) should also be taken into account.

• Environmental impacts forecast: Identification and assessment of the positive and negative future effects of the proposed project (see box 2.1). Mitigation measures, and any residual negative impacts that cannot be mitigated, should be identified. Positive effects should also be noted (e.g., less urban pollution due to a by-pass) and opportunities for environmental enhancement should be explored. The extent and quality of available data, key data gaps, and uncertainties associated with predictions should be identified or estimated. Topics that do not require further attention should be specified, with supporting rationale.

• Analysis of alternatives: Systematic comparison of the proposed investment design, site, technology, and operational alternatives in terms of their potential environmental impacts and capital and recurrent costs and suitability under local conditions. For each of the alternatives, the costs and benefits should be quantified. Criteria for selection or recommendation of alternatives should be stated.

• Mitigation plan: Identification of feasible and cost-effective measures that may reduce environmental impacts; prioritization of their relative importance, capital, and recurrent costs; and institutional, training, and monitoring requirements of those measures. The mitigation plan (also known as an “action plan” or an “environmental management plan”) should provide details on proposed work programs and schedules. Such details help ensure that the proposed environmental actions are in phase with engineering and other activities throughout the project’s implementation. The plan should consider compensatory measures if mitigation measures are not feasible or cost-effective.

• Environmental management and training: Determination of the existence, role, and capability of units with environmental skills at the local, agency, or ministry level. Based on these findings, recommendations should be made concerning the establishment of such units.

**BOX 2.1**

**U.S. guidelines for road project impact evaluation and documentation**

Guidelines prepared by the U.S. Federal Highway Administration include specific instructions for dealing with the following commonly encountered environmental impact issues:

- Land use
- Social impacts
- Economic impacts
- Air quality
- Wetlands
- Floodplains
- Coastal barriers
- Hazardous waste sites
- Energy analysis (large-scale projects)
- Farmland
- Residential and business relocation
- Noise
- Water quality
- Water body modification and wildlife
- Coastal zones
- Threatened and endangered species
- Visual impacts

*Source: OECD 1994.*
or expansion of such units and the training of staff so that the recommendations of the environmental assessment can be implemented successfully.

• **Environmental monitoring plan:** Specifications of the responsibility for monitoring, the type and cost of monitoring actions, who carries it out, who they report to, any remedial measures, and sources of funding. Special attention should be given to supervision during construction.

• **List of environmental assessment preparers:** Individuals and organizations who prepare environmental assessments.

• **References:** Materials used in preparation of the study. This list is especially important given the large amount of unpublished documentation often used.

• **Record of interagency/forum/consultation meetings:** Both invitees and attendees are listed here. The record of consultations for obtaining the informed views of the affected people and interested organizations should be included. The record should specify the means used to obtain these views. If dissenting views are expressed, these may be recorded here.

### Limited environmental analyses

For many road projects a full environmental assessment is not necessary, but some form of environmental analysis is required, with the degree of detail depending on the circumstances. One such approach is a self-standing mitigation plan, which typically has the following elements:

• **Summary:** Presenting the alternatives considered and the environmental impacts that are anticipated from the road project with and without the mitigation measures.

• **Description of and technical details for each mitigation measure:** Including the type of environmental impact to which it relates and the conditions under which it is required (e.g., continuously or only in certain circumstances), together with designs, equipment descriptions, and operating procedures, as appropriate.

• **Institutional arrangements:** Assigning the responsibilities for implementing the mitigation measures (e.g., responsibilities which involve operation, supervision, enforcement, monitoring of implementation, remedial action, financing, reporting, and staff training).

• **Implementation schedule:** For measures that must be carried out as part of the project, showing phasing and coordination with overall implementation plans.

• **Monitoring and reporting procedures:** These procedures ensure early detection of conditions that necessitate particular mitigation measures and provide information on the progress and results of mitigation.

• **Cost estimates:** Estimates should be integrated into the total project cost for both the initial investment and expenses incurred for the mitigation plan.

An example is discussed in Box 2.2. It is important to integrate the mitigation plan into the project's overall planning, including design, budget, and implementation. Such integration should be achieved by establishing the mitigation plan as a component of the project and ensuring that the plan will receive fund-

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**BOX 2.2**

**Example of a limited environmental assessment—The Philippines**

As part of a feasibility study for the restoration of rural roads after natural disasters, a number of engineering and environmental issues were considered. Components of the study included:

**Feasibility study for selected disaster spots**

• Traffic forecast

• Engineering survey

• Causes of road disasters and current restoration measures

• Types of restoration measure

• Selection of restoration measure

• Preliminary design for selected spots

• Project evaluation

**Project implementation**

• Disaster management system

• Implementation program for the rural road restoration project

• Recommendations for facilitating restoration works

*Source: JICA 1992.*
ing and supervision along with the other investment components. Specific plans should exist for:

- **Funding** (to ensure that the mitigation plan is adequately financed).
- **Management and training** (to help embed in the overall management plan the training, technical assistance, staffing, and other institutional strengthening needed to implement mitigation measures).
- **Monitoring** (to ensure that the mitigation plan is carried out and that its effectiveness can be used for the design of environmental measures for future projects).

Mitigation plans can also help strengthen environmental management capability when accompanied by information on (a) technical assistance programs, (b) staff development, (c) procurement of equipment and supplies, and (d) organizational changes. These topics are also discussed in an environmental assessment.

**Bibliography**


ENVIRONMENTAL ASSESSMENT PROCEDURES
3

Studies and tasks required for a full environmental assessment report

KEY POINTS

- Baseline data can be collected from a variety of existing records, supplemented by site surveys and consultation with local residents and agencies. The analysis should consider not only existing conditions, but also expected trends in the absence of the project under consideration.

- Impact analysis can utilize the detailed information on specific themes in part II of this handbook, covering the physical and natural environment, the human and social environment, and the activities involved in road construction, maintenance, and operation.

- Analysis of alternatives can utilize a number of formal methods for categorizing, ranking, and comparing different kinds of impact and mitigation measures. However the major requirement is a clear presentation of the key issues regarding project alternatives, as experience shows that public decisionmaking is rarely based solely on the recommendations of analytical studies.

- Avoidance, mitigation, and compensation are three approaches available for dealing with the negative impacts of road projects. While some effects can be resolved through project design, others require ongoing implementation support and provision for remedial measures where needed.

- Monitoring and evaluation of environmental actions should be provided for in an implementation plan to ensure that proposed actions are effective and that lessons can be learned for application in future projects.

KEY WORDS: Baseline, maps, photographs, databases, consultation, site surveys, types of impact, ranking, matrices, multi-criteria analysis, avoidance, mitigation, compensation, implementation, monitoring, evaluation, remedial actions
A full environmental assessment report has three major objectives: to help the managers of the road development decide on a project design that takes environmental considerations into account, to help the technical personnel responsible for execution of the road project implement it with full knowledge of the environmental factors, and to inform the public when the road project is likely to affect their environment and facilitate their participation in the decisionmaking process.

This section provides a more detailed discussion of five areas of investigation which are generally required to meet these objectives:

- Analysis of baseline conditions
- Analysis of potential environmental impacts
- Consideration of alternatives
- Development of mitigation and compensation measures
- Design of monitoring and evaluation plans.

The study requirements described here will be supplemented by more detailed discussion of methods and sources of information in other sections of this handbook. In particular:

- **Consultation** methods and options are summarized in chapter 4.
- **Impact assessment and mitigation** methods are discussed in some detail in part II, for both the physical and natural environment, and the human and social environment.
- **Maps, aerial photographs, satellite images, computer databases and programs** are reviewed in part III, with advice on potential sources of further information.

**Analysis of baseline environmental conditions**

Baseline conditions define the characteristics of the existing environment and projected future conditions assuming no project is undertaken. This provides the basis from which project impact comparisons are made. Baseline studies usually involve:

- **Collecting and analyzing existing basic documents**: These may include topographical maps, vegetation maps, aerial photographs, scientific and technical documents, and past or current project appraisal reports.
- **Assembling information from different sources**: Technical, social, demographic, and economic information can be obtained from various government departments at national, regional, or local levels and from other international, research, business, professional, or nongovernment organizations.
- **Consultation with local residents and professionals**: This can assist baseline data gathering by validating information from other sources and identifying other important local knowledge and gaps in technical data.
- **Conducting field investigations**: Including observations, analyses, and surveys. These will be necessary where existing information is inadequate or incomplete, and should be properly planned and designed by experienced professionals.

Baseline analysis is more than making a statement on the initial environment of the proposed project. Because projections of future environmental conditions that may affect the project should also be made, it is necessary to adopt a dynamic and not static approach to the study of the environment. In effect, the baseline analysis should permit a comparison of project-induced environmental changes with other expected environmental changes in the no-project situation. This dynamic approach may be more challenging, but the road agency and the environment will benefit from the additional studies and the dialogues. It should take account of: (a) past trends in environmental quality over time, (b) community preferences or competing demands regarding resource utilization, and (c) other current or proposed development programs and projects under study.

The quality of the analysis of baseline conditions establishes the viability of the appraisal of the impacts, and therefore of the study itself. The more thorough the analysis and the more relevant and well-focused the data gathered, the better the quality of the study as a whole. This stage of the development is of prime importance, for it allows the agency and the project to benefit from a thorough, patient
study of the proposed site. Hurrying to complete the project or not coordinating with the various organizations affected by the project can be counterproductive.

In assembling baseline data it is important to understand that wide variations can occur in the natural environment over long time frames. In some cases, forest maturity and natural processes such as fire can dramatically change animal habitats and human use of natural resources from one generation to the next. Longitudinal (or long-term) studies, if they exist, can be of considerable value in supplementing current environmental study data.

Analysis of potential environmental impacts

Environmental impact analysis consists of comparing the expected evolution of the site with and without the project. For each type of potential impact or environmental concern, the analysis should predict the nature and the significance of the expected impacts, or explain why no significant impact is anticipated. Some environmental effects are quantifiable, while others may need to be described qualitatively.

Part II of this handbook describes a wide range of impacts which may need to be considered. These cover the physical and natural environment (e.g., erosion, water, and animal and plant life), the human and social environment (e.g., community life, land acquisition, indigenous people, noise, and road safety), and specific issues related to the construction, maintenance, and operation of roads. Part II also provides a more detailed discussion of methods for identifying impacts on the environment, including simple methods for estimating whether impacts are likely, and more detailed analyses which may require expert assistance.

The analysis of potential environmental impact should include at least the following factors:

- **Magnitude of impact:** Quantification is relatively easy for physical effects (land cleared, trees removed, homes affected), more difficult for the biological environment (type of habitat lost), and very complex for the effects on people. For the latter, simple indicators should include the number of people affected and estimated economic losses, but wider effects on social and economic welfare should be analyzed. For some impacts, only a description of the effect is possible. Where effects can be quantified, relative indicators can help in analyzing the significance of change in each case.

  - **Time frame:** Allowance should be made for both short-term and long-term impacts. The loss of agricultural areas along the alignment of a road is an immediate impact. The retreat of a mangrove swamp following modification to the water flow or the modification of the saline threshold in an estuary generally only become apparent some years after construction. Impacts that are sudden (hazardous waste spills) or cumulative (contamination build-up in roadside soils and crops) should also be considered.

  - **Direct or indirect environmental impacts:** Direct impacts due to the presence of the road project are relatively easy to identify. Indirect impacts are more difficult to analyze but can ultimately be more important. A direct impact would be taking gravel material from a borrow pit, while an indirect impact would be increased deforestation due to easier transportation of logs. Possible impacts can be identified by considering each link in the chain of events resulting from road construction or rehabilitation.

  Where impacts are interrelated, any synergy between them should be examined, and the effects should be considered together. Margins of error and quality of basic information must be pointed out for environmental impacts that are difficult to quantify.

  Box 3.1 shows an example of impact identification for a 96 km road project in Guinea, which passes through rice-growing areas and mangrove swamps. The environmental impact study took two person-months and cost $45,000, or about 0.1 percent of the total cost of project preparation. Two site visits were made to take account of differences in environmental factors in the dry and rainy seasons.
Consideration of alternatives

As part of the road planning process, project alternatives are analyzed in terms of their ability to meet transportation objectives, such as economic development, traffic efficiency, and access, in a cost-effective manner. In the broader decisionmaking process, these technical factors are then evaluated from the perspective of community and political priorities, and available budgets. The environmental assessment should be closely integrated with this process, so that environmental factors are considered at each stage of the project analysis, and to take advantage of various consultation forums.

Alternatives which prevent or avoid negative impacts often require changes to the location of road construction or associated off-site activities. Consultation can help to identify alternatives that are practical and sustainable, and have the support of various affected and interested groups. The evaluation should avoid putting too much emphasis or resources on alternatives that are unlikely to be affordable or sustainable.

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BOX 3.1

Example of potential environmental impact identification

Environmental impact study for the Guinea-Conakry road project
(96 km road construction in a mangrove swamp and rice-growing area)

Soils
- Compaction of alluvial soils by earthmoving equipment
- Erosion and modification of surface relief of borrow zones (275,000 square meters)
- Loss of topsoil (165 hectares) in the borrow areas
- Modification of soil texture in the neighborhood of backfilling
- Over-exploitation of agricultural soils due to future development in a zone sensitive to erosion
- Irreversible salinization and acidification of mangrove swamp soils.

Water
- Modification of flowing surface water in borrow areas, causing erosion and siltation
- Modification of water flows during construction (stream diversion, modification of water table recharging)
- Sedimentation near crossings of presently cultivated flood plain
- Modification of surface and subterranean water flows and resulting drying or flooding
- Pollution of water tables by equipment lubricants, fuels, and detergents
- Displacement of salinity threshold into the mangrove swamp zone: effects on fauna and flora, impregnation of soils with tannin, erosion of coastline.

Flora
- 260 hectares of deforestation and undergrowth clearance
- Destruction of plantings (2,800 oil palms, 1,600 various trees)
- Reduction of cornice forests around swamps, from modified water flow and increased agricultural use
- Disappearance of reproduction and food zones for species of fish, aquatic and migratory birds
- Reduction of surface area of pasture land for cattle
- Reduction of mangrove plant population (habitat for fauna, purifying microfauna, firewood); erosion of the coast line
- Increase in farming activity, reduction of fallow times, impoverishment of the soils.

Fauna
- Reduction in mangrove fauna (crabs, shrimps, egrets, herons, kingfishers, spoonbills, ibises, terns, and other species)
- Increase in poaching during the works period, and subsequent hunting and fishing
- Increase in tourism (Tristao Island, the center for many migratory birds).

CONTENDED
viable. Opportunities for environmental enhancement should also be considered.

A number of structured evaluation and comparison methods have been developed for the analysis and presentation of environmental data, recognizing the difficulties involved in comparing impacts which are not easily quantified, not measured against the same criteria, and may vary in time, space, and degree of uncertainty. The most frequently used is a matrix in which the magnitude of social and natural environmental effects are represented numerically, or visually, using graphic indicators (such as dots) of the size of each effect. In either case, estimates of the relative size of each impact require judgments which are often contentious. This has led to the development of more sophisticated techniques for comparison and ranking impacts, including Delphi and multi-criteria analysis methods.

In practice, there is no technical solution which "correctly" weights and ranks the wide range of issues which need to be addressed, and the final outcomes usually are strongly influenced by political and community consultative processes which consider a few main concerns in some detail. Presentation systems should recognize this and should provide information to decisionmakers and affected groups, rather than seeking to define solutions.

The comparison of alternatives should take into account the different types of environmental impacts, with solutions described where possible according to their advantages and drawbacks. Because many impacts cannot readily be quantified or compared on sim-

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**BOX 3.1 CONTINUED**

**People**
- Loss of farms and homes (1,300 square meters)
- Reduction in agricultural production per surface unit (over-exploitation, impregnation of soils with tannin)
- Increase in consumption of wood, particularly from the mangrove swamps: erosion
- Reduction in fishing potential
- Increase in land tenure conflicts, and conflicts between farmers and nomad cattle breeders
- Increase in speed of propagation of endemic disease.

**Benefits**
- Opening the northern zone of coastal Guinea
- Sale of dried fish products (90 percent of national production)
- Sale of rice from industrial growers (3,500 hectares) and small-scale growers
- Creation of jobs
- Improved access to medical help.

**Mitigating steps incorporated in the design**
- Traffic management plans for public works vehicles and temporary diversions
- Redevelopment of borrow zones (Revegetation and stabilization of soils)
- Turfing of embankments; drainage of plains; reforestation and regeneration of plantings
- Compensation for property taken.

**Accompanying steps (integrated in regional development programs)**
- Mangrove swamp development and management plan, covering agriculture, rice growing, fishing, management of firewood, and protection of biodiversity, with provision for training, supervision and extension services
- Protection of forests; monitoring of hunting; creation of a nature reserve on Tristao island; tourism plan
- Water supply program and improvement of sanitary conditions; malaria alleviation
- Agricultural development program.

**Source:** SETRA.
ilar criteria, visual methods of presentation are often helpful. Tables of various alternatives can assist in the comparison process, for example, and a map identifying areas of geographical sensitivity can focus attention on important constraints.

Environmental issues and impact comparisons should be presented as objectively as possible, to inform and assist decisionmaking without biasing the advice given.

**Mitigation and compensation measures**

**Avoidance** of negative environmental impacts is the best approach, and often depends on the location and scale of road works and related off-site construction and traffic activities. Impacts can also be avoided by a no-project alternative, but it should be recognized that even existing roads have impacts on their surrounding environment, which may increase over time with traffic growth and land use development, and may be reduced by maintenance, rehabilitation, and construction actions.

Once a project alternative has been chosen, the environmental assessment should concentrate on design details and other provisions for impact mitigation or compensation.

**Mitigation** is the lessening of negative environmental impacts, through changes in the design, construction practices, maintenance, and operation of a road, and additional actions taken to protect the natural and social environment and individuals adversely impacted by a project.

**Compensation** should be considered if steps to reduce impact are not possible or sufficient; compensation can be material (reconstruction of homes or natural habitats) or financial (compensation for loss of property), or both.

Part II of this handbook provides a detailed discussion of avoidance, mitigation, and compensation measures which may be used for a wide variety of different types of impact. It provides information which may assist in the selection and design of these measures, specification of responsibilities of contractors, and issues which may affect their successful implementation. Opportunities for positive environmental impacts are also noted, for use either as partial compensation for other impacts, or as low-cost options for achieving environmental objectives in conjunction with a road project.

Some aspects of impact mitigation can be incorporated in project design and can be largely resolved before construction commences. Examples include roadside drainage, noise barriers, access roads, and footpaths. However, many measures require an ongoing implementation plan to ensure that proposed actions are carried out at the correct time, that environmental measures such as planting and slope protection are maintained, and that remedial actions are taken promptly when the initial measures are not fully successful.

**Consultation** can help to ensure that mitigation and compensation measures truly meet the needs of affected people and communities, and that longer-term actions in both the natural and social environments are likely to be sustainable.

A principle of *no net loss* is a useful guideline for the design of mitigation and compensation measures, especially those involving people. This requires both immediate measures and continuing efforts to ensure that former productivity and quality of life do not suffer as a result of the project.

Two additional factors to be considered in the design of mitigation and compensation plans are:

- Some measures may themselves have negative effects. Resettlement, for example, sometimes has significant impacts on existing residents or the natural environment at the new location. Social issues are the most challenging, as perceptions of “winners” and “losers” can readily develop. Equitable and balanced mitigation measures require considerable care and consultation in their design and implementation.
- Some measures may not be the exclusive domain of the road agency. Government departments, local authorities, neighbors, nearby businesses, nongovernment organizations, and the legal system may all be involved in their design and implementation. Clear definition of responsibilities, funding and reporting requirements can help to ensure the success of such measures.
Monitoring and evaluation

Implementation of environmental measures identified during the preceding studies is often the weakest link in the environmental management process and requires special attention from managers. The environmental assessment study should identify plans for works supervision and future environmental monitoring and evaluation studies. This assures continuity between design and construction and helps ensure correct implementation of the environmental plan. It should involve staff with skills and responsibilities in both environment and roads, including those concerned with work supervision during the construction phase.

Monitoring

During construction, environmental monitoring should include mitigation or compensation measures (such as noise barriers); supervision of environmental works components; and monitoring of specific environmental concerns (such as water pollution from construction activities). This requires:

- Accurately defining mitigation and compensation measures in conjunction with project detail design
- Including mitigation measures in contract specifications
- Making environmental capabilities one of the selection criteria for contractors
- Briefing, educating and training contractors in environmental protection methods.

Monitoring should not be confined to the road right of way, but should cover all sites affected by the project, including borrow areas and quarries, disposal sites, waterway diversions, materials treatment areas, access roads, and work camps.

After the construction phase, environmental monitoring must be continued. Some mitigation measures (such as drainage systems and erosion protection planting) require maintenance for correct operation, and monitoring is necessary to assure their effectiveness. Social and financial assistance to affected communities and individuals may also fail to fully address all problems, and follow-up monitoring is generally required for a number of years. Reporting requirements for environmental monitoring and responsibility for corrective measures should be clearly defined.

Evaluation

After project construction is completed, an evaluation report can test the validity of hypotheses formulated in the environmental impact study. Such evaluation is not regulated by laws in most countries and is thus neglected. This is unfortunate, as complementary studies conducted while a road is in operation serve a useful environmental purpose.

Evaluation is necessary not only for individual projects, but also to advance methodology, assist in design of future studies, and continuously improve the relevance and cost-effectiveness of environmental protection measures. Governmental support is usually necessary for successful evaluation of road projects.

Bibliography


Information, consultation, and participation

KEY POINTS

- When road projects have significant impacts on the natural and human environment, many members of the community have an interest in the way the projects are designed and implemented.

- Social analysis can help in identifying community relationships, leadership structures, and decisionmaking processes, and the presence of different subgroups in the affected communities with different impacts, interests, and priorities with regard to road project development.

- Government agencies, research institutions, and various types of nongovernment organizations may also have an interest in consultation on road projects.

- Where possible, consultation should elicit information, opinions, and concerns from the participants, rather than seek responses to narrowly defined questions.

- Community or sectional opposition to a road project can be a cause of substantial delay, increased cost, and less than satisfactory compromise solutions, which could have been avoided through earlier consultation.

- Parties to the consultation process should be given reliable and unbiased information on the problems, constraints, options available, costs of alternatives, and key criteria and objectives of the responsible government agency.

KEY WORDS: Information presentation, information gathering, participation, stakeholders, beneficiaries, implementation, displays, meetings, surveys, discussions, graphics, audiovisuals
Road projects which affect the surrounding natural and human environment often impinge upon the responsibilities, interests, and welfare of many individuals and organizations outside the road authority in charge of the project.

Throughout this handbook, consultation and communication with various interested groups is recommended as an integral part of the processes used for gathering environmental data, understanding likely impacts, determining community and individual preferences, selecting project alternatives, and designing viable and sustainable mitigation and compensation plans.

Inadequate consultation can deny the project important information which could have assisted in road planning and environmental assessment. Lack of attention to communication and consultation processes can also leave community or sectional opposition to a road project unresolved. This can ultimately be a cause of substantial delay, increased cost, and less than satisfactory compromise solutions, which could have been avoided through earlier consultation.

This section presents some of the methods which can be used to promote effective communication and consultation at various stages of the project development cycle.

**Approaches to communication**

Communication with interested parties about road projects and environmental concerns can include the following types of action:

- **Information disclosure:** Information on a project will become available whether it is planned for or not. Generally, the presence of road professionals on site is enough to stimulate curiosity. Public dissemination of clear information on the project can generally reduce later difficulties in implementation.

- **Information gathering:** Communication with residents and interest groups is equally important for finding out information which may not be readily available from other sources.

- **Consultation:** This provides opportunities for interested persons to ask questions of those in charge of the project. The opinions and suggestions heard during consultation are not necessarily binding, but they help to define the scope of the environmental assessment studies and obtain opinions about project alternatives.

- **Participation** involves a dialogue with interested parties before key project decisions are made, covering such issues as the choice of alternative routes and methods for limiting or compensating for negative environmental impact. This usually requires a good communicator at the head of the environmental team. However, the final decisions on project options generally remain with the road agency. Participation does not imply complete sharing of decisionmaking power, but recognizes shared responsibility for both negative and positive aspects of the project. Some examples are discussed in box 4.1.

**Participants**

In developing plans for consultation, the first requirement is to identify the individuals and groups who should be involved. These typically include:

- **Beneficiaries of the project**
- **Potential losers, or those at risk of negative impacts from the project**
- **Other stakeholders or parties with an interest in the project, such as local and national governments and elected officials, experts, and nongovernment organizations**
- **Others whose local knowledge may assist in identifying potential impacts and assessing the viability of proposed alternatives.**

**Local and community participants**

At the local level, social science analysis techniques can be used to examine relationships between groups and individuals, identifying those with greatest power to influence decisions and outcomes, and the forms of consultation which are most likely to elicit the knowledge and input of people with different interests, such as owners and renters, experts and laymen, beneficiaries and potential losers, men and women, wealthy and poor, farmers and businesses, rural and urban, and different ethnic groups. It is often found desirable to use several different consultation activities, such
as public meetings, expert seminars, interview surveys, neighborhood displays and small-group discussions, to successfully consult with the full range of people with an interest in a project. This is discussed further in the section on consultation techniques.

**Government agencies and research institutions**

Various government bodies can provide information on the environmental impact of the project and on future policies and plans which may affect its implementation and operations, as shown in box 4.2. Some of these organizations also have interests, responsibilities, and jurisdiction which need to be considered in selecting project options and designing implementation plans.

Inclusion in the assessment process at an early stage helps to develop an enduring role in seeing that mitigation measures are applied.

Apart from road and environment departments, useful information can be obtained on national statistics organizations and departments dealing with demographic, cultural, and economic data and trends that are important in evaluating social impacts. Sectoral agencies can provide information on direct and indirect impacts of road development on agriculture, mining, forestry, or water supply, including basic data on supply, production, and distribution constraints. Other departments and research institutes can provide data on the natural environment. In many of these areas, local governments can provide additional information on site-specific conditions.

Government organizations also have a role to play in project decisionmaking and implementation. Decisions on land use, national parks, and indigenous people, for example, often involve departments outside the road ministry. Implementation of mitigation and compensation plans and enforcement of regulations regarding safety and pollution may also involve other groups, who should therefore be involved in the design of these components.

**Nongovernment organizations**

A wide variety of nongovernment organizations (NGOs) can be found in different countries and regions, with different capabilities, strengths, and interests in the relationships between road projects and the environment. These groups may be oriented around com-

**BOX 4.1**

**Community participation in project decisionmaking**

In many industrial countries, community representatives are being given an increasing role in road project decisionmaking. The following examples are indicative of a growing trend:

In South Birmingham, U.K., road planners were faced with vigorous opposition to new road proposals, from a number of community and environmental groups. To resolve the conflict, anti-road groups were invited to come forward with practical alternatives to resolve traffic problems. The cooperative approach led to identification of road modifications which reduced speeds but maintained capacity in built-up urban areas. Perhaps more importantly, the resulting proposals were put forward jointly by road planners and community groups.

In Sydney, Australia, polarized community views of the Botany-West Transport Study led to the formation of a Community Advisory Committee to assist in the preparation of briefs and management of the study. A consensus approach was adopted for decisions, all committee members had equal status, and information was shared openly. Because the study was considering very expensive infrastructure options, final decisions rested with the state government, but the committee had substantial authority and control over the process, in contrast to traditional government agency decisionmaking procedures. Three workshops and four newsletters (each seeking some feedback) were used to get wider public input from industry, unions, local government, and other interest groups not directly involved in the advisory committee. The study looked first at what sort of future people expected to live in, and then what major transport and land-use options, projects, and policies would be needed.

munities, ethnic groups, business interests, unions, professions, or issues such as transport, development, poverty, or the environment. In some cases they have significant resources and contacts within their interest group, and can represent the views of a significant segment of the wider community.

NGOs can bring important information and skills to the environmental consultation process. For example:

- Community and ethnic NGOs can provide awareness of local issues and the socioeconomic context of project options. They may also provide an additional interface with residents and local groups to assist the consultation process.
- Environmental NGOs have the advantage of knowledge about a specific area and how development affects its status. They can often help to identify fragile species and contribute to the design, organization, and follow-up of protective measures.
- Development-oriented NGOs may be involved in complementary development operations, and can assist with implementation issues. Measures to control water runoff, for example, can be designed as part of an NGO’s irrigation project. On the other hand, road improvements can enable an NGO to launch projects that have run up against obstacles, such as the marketing and distribution of fruit and vegetables.

**Consultation techniques**

All of the forms of consultation and communication discussed here include some or all of the following components:

- *Establish the “rules of the game,”* that is, the role of this consultation activity in the overall process of road planning and decisionmaking. What types of information need to be elicited, and how will decisions be taken? This information can help to focus discussion on issues most relevant to the current stage of environmental analysis of a project.
- *Provide information,* for example on the project objectives, the problems it aims to address, and alternatives considered to date.

### BOX 4.2

**Departments consulted for an impact study of a road in Burundi**

<table>
<thead>
<tr>
<th>Ministry of Public Works and Urban Development</th>
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<tbody>
<tr>
<td>General Directorate</td>
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<td>Highways General Directorate</td>
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<td>Director of Design Office and Inspection</td>
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<td>Ministry of Planning</td>
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<td>Higher Institute of Studies and Statistics</td>
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<td>Ministry of the Environment, Tourism and Development</td>
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<td>Environmental Counsel</td>
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<td>Directorate of Forests</td>
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<td>Directorate of National Institute of the Environment and Preservation of Nature</td>
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<td>World Bank counselor</td>
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<td>Burundi Institute of Agronomic Sciences</td>
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<td>General Directorate</td>
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<td>Agro-Economic Research Department</td>
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<td>Cartographic Department</td>
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<td>Directorate of Geology and Energy</td>
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<td>Special Public Works Program</td>
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<td>Integrated Breeding Promotion Project</td>
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<td>National Reforestation Project</td>
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<td>European Communities Commission</td>
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<tr>
<td>United Nations Development Programme</td>
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<td>French Aid and Cooperation Fund</td>
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*Source: SETRA.*
Supporting data may be provided on current traffic and travel patterns; economic, social, and environmental issues; and geographic and budgetary constraints.

- **Seek input.** This may begin with concerns of those consulted, and better information on travel, social, and environmental issues that may affect project impacts. As the options and issues become clear, input may be requested on priorities and potential solutions to identified problems.

- **Discuss implementation.** Local knowledge can be very helpful in ensuring that proposed measures can work and are likely to be sustained.

  This process may take place on more than one occasion in the development of a project and, through more than one technique, to reach different interest groups. For larger projects, it is common for initial consultation activities to provide and elicit information, while later meetings discuss solutions and their implementation, perhaps after more analysis and investigation.

**Information displays and reports**

Public displays, newsletters and leaflets can be used to provide information on initial concepts and proposals for a project, and subsequently on options selected and designs adopted. Displays are usually presented in public buildings, busy roadside areas, shopping areas, or markets, especially those close to the affected areas. Where possible, project staff should be present to answer questions and accept verbal or written comments, which can be incorporated into project planning and environmental assessments.

**Interview surveys**

Surveys are widely used in gathering sociological data and can also quantify opinions, priorities, and concerns of people affected by road projects. A common approach is to interview a representative sample of affected people and ask a predefined set of questions, with responses recorded on a standard form. Careful survey design is important to ensure that the sample interviewed is truly representative of the affected groups and that questions are worded so as not to bias responses. Expert assistance is often required in the design of survey procedures, training of interviewers, and interpretation of results.

Because of the time and expertise required, surveys can be expensive and are not used for all cases.

**Public meetings**

Formal “public hearings” are required for major public projects in some countries, with specific procedures laid down by legislation. The methods vary from case to case and are not discussed further here.

Many other forms of public meeting are used to facilitate information, consultation, and participation in road project evaluations. In general, these should follow the four steps outlined earlier: establish “rules of the game,” provide information, seek input, and discuss implementation.

An understanding of social structures and community cultures is most important in the conduct of meetings. Organizers should take account of leadership structures, decision-making processes, and the presence of powerful or vocal groups within a meeting. Meeting arrangements should allow for different cultural approaches to collective decisionmaking or public disagreement. The existence of subgroups with substantially different interests, or groups who are unlikely to speak up in public forums, should also be recognized.

The choice of time and location of meetings can have a big effect on attendance and participation. In general, meetings which are held closer to affected communities, and in familiar buildings, are more likely to encourage local participation.

In some cases, formal notes or minutes may be recorded for public meetings, along with the names and affiliations of participants. This can be particularly important for participatory decisionmaking processes.

Public meetings do not always result in improved communications. Sometimes powerful minorities “hijack” the consultation
process, or vocal groups express strong opinions to the exclusion of other viewpoints, or tensions arise between different interest groups or within communities. And in some cases the meeting can end with uncertainties about project objectives, scope, impacts, or options. Many of these outcomes can be avoided by thorough preparation and a sound understanding of the participants involved.

An experienced and respected moderator or facilitator, independent of the agency proposing the project, can help to ensure the effectiveness of such discussions. It is important, for example, to make sure that participants have the opportunity to express their views, that these are properly understood, and that commitments for future action are clearly distinguished from opinions and examples.

Good communications skills are important for the conduct of public meetings; they can help, for example in probing areas of uncertainty and objectively restating information and opinions.

**Individual or group discussions**
In addition to public meetings, separate discussions should be arranged with specific groups or individuals. These meetings should be seen as an opportunity to improve communications with diverse interest groups, but not as a way of giving unbalanced influence over the project outcomes. They have a number of objectives.

In some cases, the views of minority groups or less powerful elements of a community, such as squatters, renters, women, and the poor, may be best discussed in smaller and less formal settings. Arrangements for such meetings should recognize social and cultural norms in the local communities. In some cases, participants may prefer comments to be anonymous, in aggregate form, rather than being attributed to individuals.

On the other hand, some groups and individuals have particular knowledge and interests which might justify a more in-depth discussion that could not be accommodated at a general meeting. Examples include affected residents, technical specialists, councillors or political representatives, nongovernment organizations, specific community groups, and specific businesses or occupational groups. Where appropriate, separate meetings can be arranged in which information is presented for a more specific audience, and discussion can focus on clearly defined concerns and issues.

**On-site consultations**
This approach is especially suited to cases with time or other constraints (such as the absence of meeting facilities), or when on-site discussions will be particularly helpful to either the agency or meeting participants. It is also useful for pre-bid discussions with potential contractors, to make sure that environmental issues and responsibilities are clearly understood.

If a site inspection tour is included, the number of participants may need to be limited, according to the number of road project staff available.

**Rapid appraisal methods**
As it is frequently difficult to allocate the time and resources necessary for detailed community surveys and in-depth studies, there is growing interest in a range of alternative and less-structured methods of social data collection. These are collectively referred to as rapid appraisal techniques and include such methods as key informant interviews, focus group discussions, group interviews, structured observation, and informal surveys. Kumar (1993) describes the underlying rationale and methodology and their relation to more formal social science methods, and provides numerous examples and case studies to illustrate their practical application. The Overseas Development Administration notes five common characteristics:
- Greater speed compared with conventional methods of analysis
- Work done in the “field”
- Emphasis on learning directly from local inhabitants
- Semistructured, multidisciplinary approach with room for flexibility and innovation
- Emphasis on timely insights, hypotheses or
“best bets” rather than final truths or fixed recommendations.

Sketch maps are often used as part of this approach, along with “transects,” or diagrammatic representations of land use accompanied by notes about problems and opportunities. Some examples are shown in boxes 4.3 and 4.4.

**Presentation methods**

Information about environmental aspects of roads often covers a wide range of technical issues, which may vary in space, time, and degree of uncertainty about likely outcomes. For effective information and consultation, the key points need to be summarized and presented in ways which are easily understood by various audiences and provide an objective description of the main factors of interest. The presentation needs to allow comparison of impacts which are not readily quantified in common terms, and may provide different levels of detail when used for residents, experts, and decisionmakers.

The following are some useful considerations in the use of presentation techniques

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**BOX 4.3**

**Rapid appraisal techniques: the village sketch map**

The village sketch map is a spatial representation of the community.

*Process:* The assistant chief already had a 1:50,000 topographical map. The team traced a base map, then the team, two village elders, and the assistant chief drove all roads and lanes in the entire sublocation—a trip of about two hours—recording information and talking with people, as appropriate.

*Result:* The map exercise identified three micro-zones, defined largely by elevation, soils, and rainfall. The Upper Zone had somewhat higher rainfall, generally fertile soils, and potential for growing coffee. The Lower Zone was generally drier, had few water sources, and generally lower agricultural potential.

*Usefulness:* Knowing about micro-zones, disparities in wealth, differences in land use, and variations in resource access provided an opportunity for the assistant chief, women’s group leaders, and the appraisal team to locate areas where local leaders thought there were particular problems. Having this initial visual reference provided common ground for the team and local leaders to exchange information.

*Assessment:* Preparing sketch maps as a first step has proven to be a dramatic and visually important way to announce to the community that something is going on. Several teams have had excellent responses in having the communities prepare their own sketch maps. The exercise is one of the most important rapid appraisal data-gathering tools.

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Source: Kumar 1993.
and media:
- **Oral communications** should be adjusted to the occasion (e.g., size of group) and the audience (e.g., language, degree of technical detail). It is important to distinguish between fact and opinion, and between firm plans and options. Dialogue requires active listening to views expressed.
- **Written reports, newsletters, and leaflets** for general audiences should use clear and concise expression, avoiding long sentences and technical terms or jargon. Illustrative material such as diagrams, photographs, and maps can be very useful. Summaries can highlight important points, and graphs or charts can simplify the communication of some numerical comparisons or trends.
- **Graphic material** should also aim for simplicity and clarity of message in order to be meaningful to nontechnical audiences. This often means leaving out some information so that important issues are highlighted. Tables and matrices, for example, should avoid fine print and excessive detail where possible; posters should emphasize only a few messages; and maps should limit the detail presented on options or background. Aerial maps and satellite images, if available, are also valuable in describing a site and its environmental components.
- **Audio-visual aids** such as slides and video can be used to describe the site and surrounding environment, give an impression of the improved road and traffic situation, or present examples of impacts experienced elsewhere and mitigation measures used. Text slides or transparencies should use large fonts and present only very simple messages. In meetings where dialogue is important, visual presentations requiring darkening of the room should be used sparingly.

**BOX 4.4**

**Rapid appraisal techniques: Information about village institutions**

While the sketch map and seasonal calendar reveal important physical information, the institutional diagram has become an essential device for gathering social and institutional data. The team first compiled a list of all institutions (church groups, women's organizations, cooperatives, etc.) in the sublocation. Meeting with clusters of men and women in four different sites of the sublocation, the team asked residents to rank the importance and cooperation of village institutions. To facilitate this process, the team leader brought 30 to 40 circles, cut from paper. The team leader asked group members to place names of the community's institutions on the labels, using large circles for the influential groups and smaller circles for less important ones.

Next, the group leader asked villagers to arrange the circles to show how different institutions in the community cooperate to get things done (see figure). If two groups worked closely together, the circles would be placed to overlap one another. If the groups had no record of collaboration, circles would be placed separately from each other.

While details varied, they all identified the important role of women's groups, as well as of government institutions in Mbusyani. For Mbusyani, they confirmed that the women's groups were the best bet to supervise follow-up work, raise and manage funds to do the work, and to cooperate with the assistant chief to plan new activities. In another community (not Mbusyani), the institutional analysis revealed that no village group trusted the assistant chief or would work with him. Many other examples of such insights could be cited. The point of the village social analysis is the depth of understanding and the action imperatives that can be derived from a half-day discussion of the village's social and political profile, as perceived by representatives from the community.

*Source: Kumar 1993.*

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**ROADS AND THE ENVIRONMENT: A HANDBOOK**
Bibliography


Management and institutional issues

KEY POINTS

- Environmental specialists within a road agency are required to undertake small studies, plan and manage larger environmental studies, and coordinate with environmental specialists in other government agencies, research institutions, and the private sector.

- Environmental skills are required not only in the conduct of studies for road planning, but also in the design and maintenance of roads and the implementation of mitigation plans and monitoring plans.

- Legal and policy issues need to be closely monitored and coordinated with other branches of government.

- Training programs are important for creating or reinforcing the environmental assessment ability of groups concerned with roads and the environment. Training programs are most effective if scheduled far ahead in the project cycle, and they should be adapted to the tasks of the personnel concerned.

KEY WORDS: Communication skills, natural sciences, social sciences, project management, contract clauses, training
Responsibility for environmental studies
Organizational arrangements for the conduct of environmental studies can vary in line with the general objectives of the study, the skills required, the resources available, and the nature and size of the project.

Environmental specialists are generally needed within a road agency to undertake small studies, coordinate and manage larger studies, and coordinate with other departments and agencies with environmental expertise. To complement the planning, engineering, and economic skills of the road agency, environmental specialists should bring a knowledge of the social sciences, natural sciences, and consultation methods.

- For small projects with limited environmental problems, in-house environmental specialists can carry out the entire study personally, perhaps with advice and assistance from other specialists. This experience is important as it develops skills which may be helpful when carrying out larger projects.
- For larger projects, environmental studies may be carried out by contract, or through a combination of in-house analysis, coordination with other specialist agencies, and subcontracts to consultants or universities for specific components. Where a full environmental assessment is required, the work can be executed by engineering consultants with an environmental division or by consultants specializing in environmental studies. In-house environmental specialists are needed to establish terms of reference for such studies, evaluate and supervise consultants, assist with public consultation processes, and coordinate with project planners and other environmental experts.

Responsibility for implementation of environmental actions
Environmental skills are also required in a road agency for the various stages of implementing project actions related to the environment. These include land acquisition, preliminary design, detailed design, contract specifications, construction supervision, maintenance, and follow-up of mitigation plans related to both the social and natural environment.

By working with road engineers and planners on route choice and design, environmental specialists can ensure that community and environmental issues are incorporated into project formulation at an early stage and increase awareness of environmental factors throughout the design process. The environmental specialist should identify potential needs for liaison with outside experts, for example on landscape, wildlife protection, or the design of improved water retention schemes.

Contract specifications
Contract specifications are required for implementation of mitigation measures as part of the overall construction work, such as tree removal, revegetation, construction traffic management, and cleanup of work sites. Certain measures, such as relocation of animal species (temporary or permanent), reforestation, and resettlement, may require the services of specialist subcontractors. Examples are illustrated in box 5.1 and discussed further in chapters 18 and 19 of this handbook.

Construction supervision
Most construction work requires the presence of an inspector, either from a government road agency or as part of a consultant’s office, to ensure that the technical clauses of the contract are respected. Environmental issues considered during works supervision could include:

- The stockpiling of soil during the preparation of the right of way; its location, duration of storage, and reutilization
- Replanting of exposed slopes and other surfaces, and the follow-up maintenance and watering of new plantings.

Maintenance and operations supervision.
These supervisors take responsibility for protecting the installations once construction is completed. Timely action can be critical to the protection of the environment. For example, maintaining drainage ditches and
structures avoids large-scale erosion during major storms. Monitoring mitigation measures during operations helps to ensure that maximum benefit is obtained from the cost of the installation.

Apart from the maintenance of physical infrastructure, attention must also be given to social mitigation measures (ongoing support for affected residents and businesses), natural habitats (success of reestablishment of plant or animal species), and traffic management (accidents and impacts on adjacent properties).

Policy and legal considerations
Regulations, laws, decrees, circulars, and sometimes policy guidelines or international conventions are generally the responsibility of environmental agencies totally independent from road administrations. Interagency coordination is therefore necessary to take into account these considerations in road and traffic specifications. One of the major roles of environmental specialists within a road agency is to keep abreast of the requirements of regulatory agencies and to develop an effective dialogue with them during the preparation of new regulations.

The environmental assessment or environmental management plan should note the various national requirements that apply. Financial, physical, or other criteria should be clearly identified. This is important with sectoral environmental assessments covering a range of projects, where several different procedures may be used. Failure to follow regulations such as the following can block the progress of a whole project:

- Regulations concerning procedures and methodology (particularly important for environmental assessment reports)
- Regulations concerning environmental standards (important for management plans)
- Methodology for carrying out the environmental assessment: Certain regulations require that studies be carried out in a particular manner and be presented in specific format
- Supervision of the study: Specify the conditions under which the authorities responsible for the environment will intervene in the environmental assessment and the extent of their prerogatives.

Regulations are extremely important because they usually specify standards for the environmental specialist and those responsible for the studies to evaluate the acceptability of the project and the measures to be taken in order to protect the environment. Requirements of national, regional, and local governments, and any financing institutions, should also be taken into account.

The standards covered are quite diverse: air, noise, quality of the water and the soil, the protection of natural surroundings or archaeological sites, public health, and others. An

<table>
<thead>
<tr>
<th>BOX 5.1. Environmental sections of tender documents</th>
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</thead>
<tbody>
<tr>
<td>Prequalification of contractors may require submission of an environmental protection statement and health and safety statement, which should then be developed into full action plans in the final bid. Contract specifications vary with the project and surrounding environmental issues, but may include:</td>
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<tr>
<td>• Locations of and working methods in borrow pits and quarries</td>
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<td>• Protection of irrigation facilities, and maintenance of crossroad irrigation during and after construction</td>
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<tr>
<td>• Requirements for full reinstatement of land to its ultimate stable and productive use</td>
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<tr>
<td>• Controls on the location, design, and operation of contractor’s camps and facilities</td>
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<tr>
<td>• Controls on the use of wood for any purpose, and provision of alternative fuels to the work force to minimize demands on local firewood</td>
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<tr>
<td>• Arrangements for provision of food and supplies for workers to minimize local price inflation</td>
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<tr>
<td>• Controls on waste disposal methods</td>
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<tr>
<td>• Provision of health facilities for the work force, including antimalaria measures.</td>
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</table>

MANAGEMENT AND INSTITUTIONAL ISSUES
Environmental assessment may simply refer- ence the appropriate standards, without providing all the details, except where this is particularly relevant.

Although it is not possible to deal with regulations for all of the elements above in this handbook, useful references can be found in part II. During the monitoring stage the particulars of regulatory standards may be of great importance and should be referenced in project documentation or be readily available.

**Environmental assessment team organization**
The management of a road agency should be assisted by a specialized environmental staff with expertise in the natural sciences, and the capability to perform the following functions:
- Defining policy directions
- Conducting or arranging for environmental assessments
- Ensuring internal coordination
- Negotiating with other administrations (environment, agriculture, planning)
- Staying abreast of, developing, and enforcing regulations
- Defining priorities
- Implementing mitigation plans

- Developing methods and operational tools for environmental awareness at policy, program, project, and operations levels
- Organizing training and information campaigns.

The following organizational options should be considered:
- An advisor to senior management, with limited operational responsibility
- A small-scale coordinating unit responsible for defining programs, monitoring, evaluating and communication. Most work would be contracted out to consultants
- A more comprehensive structure that performs most work in-house and uses consultants for specialized topics.

Two conditions are essential to success:
- A strong relationship with management
- Listening to the needs and requirements of operational, construction, and management teams within the road agency and being responsive to the concerns of other agencies and the public.

An example is shown in box 5.2. In addition to forming a headquarters unit, there may be a need to strengthen field environmental capabilities by establishing on-site units. It is a good practice to describe the agency’s environmental organization in any

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**BOX 5.2**

**Establishing an environmental unit in a road department—Morocco**

Morocco has undertaken environmental impact studies of specific projects for some time, especially for freeways and roads in sensitive ecological zones and built-up areas, but the approach has not been systematic or required by legislation. Following the “Earth Summit” in Rio de Janeiro in 1992, a national Ministry of Environment was established, and a “roads and environment” unit was created in the Department of Roads and Traffic, with the objectives of:

**Short term**
- Sensitization of public and private professionals
- Model studies and demonstration projects to involve sector staff
- Research and monitoring of environmental impacts of roads
- Developing environmental impact study directives and methodology
- Collaboration with other agencies on development of laws.

**Medium term**
- Establishing a multidisciplinary environmental audit team
- Preparing regulations regarding environmental assessments for roads.

*Source: Ministry of Public Works, Morocco.*
sectoral or project environmental assessments that are prepared.

**Environmental training programs**

Training in environmental skills is required both for environmental specialists working on studies, mitigation plans, and supervision of project implementation, and also for the staff or road agencies, contractors, and consultants responsible for planning, designing, constructing, and managing roads. Ultimately, the success of environmental assessment processes depends on the awareness of environmental factors at all levels and stages of the project cycle, and on the motivation to deal with problems which may arise.

The training process is used to create or reinforce environmental diagnosis, planning, and management capabilities of the road agency and its environmental assessment team. The environmental assessment field needs to overcome major shortages in human resources in many countries, including:

- Insufficient technically qualified staff, especially at the intermediate level
- A lack of practical and on-site experience, which may cut staff productivity as increased attention is given to environmental issues
- Job turnover, and institutional structures not geared to the needs of environmental assessment and mitigation activities
- A shortage of environmental instructors in many countries with knowledge of specific fields of importance for road projects.

During the transition period when awareness of environmental issues is being developed, a strategic training plan should be prepared, with training activities aimed at the following groups:

**Management**

Training aims principally to make understood the general environmental assessment policy of the roads department, which is the basis of the environmental assessment directives and procedures. In this way, management will be able to mobilize, convince, and guide their coworkers. This type of training can be carried out at seminars of one to two days for groupings of 50 or more participants.

**Technical specialists**

This type of training is addressed primarily to engineers and their colleagues who are responsible for planning, designing, and implementing projects.

- For those directly responsible for environmental components, training should include case studies and exchanges of actual experiences, as in the preparation of environmental assessment reports. Training can be of one to two days in length but with a smaller group of 30 to 40 participants. The objective is to improve understanding of the issues and procedures to be followed in environmental assessment work and to transmit the practical knowledge and tips needed in day-to-day work.
- For other engineers and professionals in road agencies, local government, universities, and private practice, training should focus on increasing awareness of environmental issues at various stages of road development and management.

**Site supervisors**

This training is intended to provide in-depth methodological, technical, and practical knowledge covering all the activities of supervising the construction work and maintenance. These types of training should only be conducted by those having practical experience and is only aimed at groups of 20 to 30 participants. Case studies and site visits are indispensable.

Training content should be tailored to meet the needs of each group. It may include technical methods and procedures concerned (e.g., for erosion protection, noise analysis), guidelines for organization and management (e.g., for study design and integration with project planning), techniques for communication with the public, and an introduction to ecological and social analysis. The instructors should be scientists or researchers specialized in the natural and social environment, and highway professionals who already have field experience with environmental assessment and road project procedures.
A training program of the type described here can be established and implemented over a period of one or two years. Subsequent training is required to keep abreast of changes in the field of environmental studies and to see that these new procedures are adopted.

**Bibliography**


Part II

Environmental impacts and mitigation measures
Types of environmental impact

Part II provides a more detailed, in-depth discussion of each of the major factors involved in environmental assessment and impact mitigation for road projects. For each topic, practical information is provided on possible impacts, how to identify and assess them, and some common mitigation options. This is followed by an environmental study checklist and a bibliography. Sections are designed for quick reference and should help the reader:

- Determine whether significant problems are likely or possible under each heading
- Evaluate useful indicators of environmental impacts
- Assess the need for expert assistance and write study terms of reference
- Consider all options for mitigation of impacts and related implementation issues
- Identify opportunities for positive environmental actions
- Consult with interested and affected people and incorporate their knowledge and preferences into environmental decisions
- Develop environmental action plans with clear responsibilities, resources and follow-up procedures
- Identify and review legislation and regulations affecting environmental issues
- Include environmental responsibilities in contracts and contract management
- Access more information.

The topics or themes discussed in this manner are:

**Physical and natural environment**
- Soil and erosion
- Water
- Air quality
- Natural environment (flora and fauna)

**Human and social environment**
- Community life and economic activities
- Land acquisition and resettlement
- Indigenous or traditional populations
- Cultural heritage
- Aesthetics and landscapes
- Noise
- Road safety

**Managing road works and traffic operations**
- Construction and off-site activities
- Rehabilitation and maintenance practices
- Risks associated with road works and traffic operations.
In practice, many of these factors are interrelated. The following introductory text discusses some of these linkages, in terms of the natural environment (the ecosystem), the human and social environment (including urban issues), and different types of impact on the environment.

This handbook should not be viewed as a cookbook with recipes to be applied systematically in all situations. Methods and approaches will need to be adapted to the specific needs of each project, environment, country, and community. Nevertheless, project management processes should be organized so that environmental matters are considered, gathered, analyzed, and weighed, and have a timely influence on the planning, budget, and design of the road project. The environmental approach is not aimed solely at putting the project in the context of the proposed environment, but also at optimizing the positive impacts of the road project on its environment.

**The ecosystem**
The environment cannot be comprehended by merely juxtaposing separate assessments for each environmental component. Environments are made up of natural ecosystems and human social systems, and environmental factors often affect one another profoundly.

An ecosystem is a functional entity, a community of plants and animals (biocenosis) living in a space with globally homogeneous ecological conditions (the biotope). Humans are an integral part of these systems and affect them by acting on the biocenoses and the biotopes, by which they are affected in turn.

The ecosystem constitutes the basic structural unit of the biosphere. Each ecosystem covers a land or ocean surface in which homogeneous conditions reign, regardless of its scope. Dimensions can be defined in a few square kilometers or in thousands of square kilometers, depth can vary from a few centimeters (desert soil) to dozens of meters (tropical rain forests) or kilometers (ocean environment).

One characteristic of the natural environment is that it continually evolves. It has its own dynamics linked with interaction between biotope and biocenosis.

Humans inhabit, and are part of, this complex and fragile system, and it is in their best interest to protect it. Through intervention (agricultural, pastoral, sylvicultural, hydraulic, and other management), humans can maintain the environment at a given evolutionary phase, but as soon as the intervention stops or slackens, the spontaneous dynamics take over. Road construction and traffic operations can act on each of these factors.

**Social and urban environments**
This handbook is written primarily for rural and interurban roads. It also has considerable applicability to built-up areas, but does not take account of all of the factors affecting large urban environments.

Urban areas generally have more complex traffic networks and more competition between travel modes. Changes in road infrastructure can significantly affect urban form and the quality of urban life. It is therefore important to analyze road system changes in the context of broader urban planning goals and long-term strategies for urban growth and change.

Issues such as noise, air quality, and resettlement are primarily urban concerns, and environmental problems related to community life and safety in large towns are generally different from those experienced elsewhere. Urban areas typically have more constraints on road space, more traffic congestion and road accidents, more conflict between road use and other human activities, and higher costs of road works and related environmental measures. Typically, they also have more people living and working close to roads and traffic.

**Consultation** is especially important for urban locations, to identify potential impacts and sources of information from local knowledge, to highlight community concerns about the effects of road changes on lifestyles and welfare, and to encourage participation in the development of workable solutions.

Three approaches to environmental mitigation which may have applicability across a
number of specific impact types are:
- **Control of land use and access** adjacent to roads is an important factor in limiting environmental conflicts between roads and urban communities and is especially applicable to new and improved roads and to roads in urban fringe areas. Attention to planning, design, and land use can simultaneously improve both the amenity of local communities and efficiency of road operations.
- **Restricting motorized traffic**, for example through: limits on heavy vehicle access to specific roads or areas; restraints on all motorized vehicles entering specific areas; emphasis on certain modes of travel, such as bicycles, buses, high-occupancy vehicles, and pedestrians, using priority measures or exclusive routes; and pricing of access or parking in congested urban areas.
- **Positive environmental actions** associated with road projects, to improve the amenity of a local community in compensation for the overall impact of a road project. Typical examples are small design changes which improve local accessibility, parkland, shopping areas, or other facilities, developed in consultation with local residents.

### Road construction, maintenance and operations

Three chapters of part II deal with environmental issues arising during the construction, maintenance, and use of roads. These actions are closely linked with the discussion of specific types of impact, as illustrated in table 6.1.

#### Different types of impact

Impacts of human activities on the environment can be categorized or classified according to:

- The **cause** of the impact:
  - Direct and indirect impacts
  - Impacts of the road and related facilities
  - Cumulative effects of the project.

- The **type or quality** of the impact:
  - Positive and negative impacts
  - Specific or widespread impacts
  - Temporary or permanent impacts
  - Random or assured impacts
  - Reversible or irreversible impacts
  - Short- or long-term impacts.

#### Direct and indirect impacts

Direct impacts are caused by the road itself (road building processes such as land take, removal of vegetation, severance of farmland). They are generally easier to inventory, assess, and control than indirect impacts. Indirect impacts (also known as secondary, tertiary, and chain impacts) are usually linked closely with the project and may have more profound consequences on the environment than direct impacts. Indirect impacts over time can affect larger geographical areas of the environment than originally anticipated. Examples include pollution of a river caused by polluted

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**TABLE 6.1**

Environmental issues arising during road works and operations

<table>
<thead>
<tr>
<th>Environment</th>
<th>Construction</th>
<th>Rehabilitation and maintenance</th>
<th>Operations</th>
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<tbody>
<tr>
<td>Soil and erosion</td>
<td>+++</td>
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<tr>
<td>Water</td>
<td>+++++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Air quality</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Natural environment</td>
<td>+++++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Community life and economic activities</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Land acquisition and resettlement</td>
<td>+++++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Indigenous or traditional peoples</td>
<td>+++++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cultural heritage</td>
<td>+++++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Aesthetics and landscapes</td>
<td>+++++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Noise</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Road safety</td>
<td>++</td>
<td>+</td>
<td>+++</td>
</tr>
</tbody>
</table>

**Note:** +++ Excellent analytical efficiency gains for resources expended. ++ Good cost efficiency. + Limited cost efficiency.
roadbed runoff (figure 6.1), and urban growth near a new road.

**Impacts of the road and off-site activities associated with road construction**

Environmental impacts should be predicted not only for the road right-of-way, but also for sites associated with the road project, such as: deposit and borrow sites, materials treatment areas, quarries, access roads, and facilities provided for project workers.

**Cumulative effects**

Cumulative effects, also called synergy, refer to global effects which are greater than the sum of the effects of elementary causes acting separately. The result of the combined impacts may affect the area more profoundly and may increase the geographic scope of the impacts (figure 6.2).

**Positive and negative impacts**

Positive impacts which occur on project completion typically include improved access, reduced travel time and cost, and perhaps reductions in accidents or noise. Other positive outcomes can be designed into a project, for example to improve water retention for local use, drain unhealthy swamps, or provide better facilities for pedestrians and bicycles. In some cases, positive impacts can appear without having been initially foreseen by the road agency, for example through use of borrow sites to water livestock in dry areas.

The emphasis of this handbook is primarily on avoiding and mitigating negative impacts, which should be a high priority in all road projects. Environmental impacts sometimes have both positive and negative effects: some impacts can positively affect some people and negatively affect others in the same environmental area. For example, a concrete pipe culvert might be useful to a fisherman to stretch his nets, but it might damage the farmer’s irrigation system.

**Specific or widespread impacts**

Specific impacts concern the immediate vicinity of the road, such as destruction of a building, modification of access to a farm, or rechanneling of a waterway. Widespread impacts can occur many kilometers from the project. These impacts are often linked to chain effects that arise over the medium- or long-term existence of the project, including settlement of farmers, deforestation, and development of new industries.

**Temporary or permanent impacts**

Temporary impacts mostly occur during the work phase of a project (e.g., noise from construction machinery, siltation of waterways,
dust), or shortly afterwards (e.g., reestablishing businesses affected by the project). In either case, they will diminish and cease to exist after time. Permanent impacts occur both during work and after completion and will affect the human and natural environment indefinitely. Examples include modification of the landscape, disappearance of farmland, noise caused by traffic, and severance of previous travel paths.

**Random or assured impacts**
In the preliminary analysis of the environmental impact assessment, it is useful to make a distinction between assured or highly probable impacts (in a country with high, densely settled populations, the creation of a road through virgin land will probably result in population migration), and more random and unpredictable ones (accidental pollution, fire, spillage of toxic products). Effects with a low probability of occurring, but which nevertheless may have serious consequences on the environment, are discussed under risks.

**Reversible or irreversible impacts.**
Reversible impacts are those for which it is possible to return to the initial environmental state, or at least for which there will be no harmful long-term consequences on the envi-

---

**Figure 6.2 The synergy effect: Example of a stream**

Each elementary action produces a certain effect or a risk that can be limited, but the combination of such actions and therefore their consequences may be the source of significant effects. In this example, steps can be envisaged with reference to each elementary action, in order to avoid the synergy effect.
Irrversible impacts never allow the environment to recover its initial state and may create more constraints on the environment.

**Short- or long-term impacts**

Short-term impacts are those which appear during or shortly after construction; long-term impacts may arise during construction, but many of their consequences appear during the operational phase.

**Ranking effects by their environmental impact**

To qualify environmental impacts by the type of effect they have on the environment is not sufficient. Impacts must also be categorized by the gravity of impact they will have on the environment. The most damaging and longest lasting impacts will obviously be the first to be avoided or mitigated.
Soil and erosion

**KEY POINTS**

- Erosion is one of the most common environmental impacts of road projects, resulting from interactions between water flow and soil, both of which are disturbed by road construction.

- Soil instability on slopes is also an environmental consideration for road works.

- Prompt replanting of exposed soils and attention to drainage of roadside slopes will minimize problems.

- Existing roads and previous projects can provide examples of past environmental problems and successful treatments.

**KEY WORDS:** Erosion, slope, drainage, planting, retaining wall
Soil is a medium for many biological and human activities. It affects how ecosystems function and supports agriculture and other human activities. Many of the impacts linked to the soil are also discussed in the chapters on water (groundwater, pollution), natural environment (effects on flora and fauna), and construction, rehabilitation, and maintenance.

In the road itself, in borrow pits, or around rivers, there are many examples of erosion. Losses can be considerable for the road agency and others, including farmers losing crops and land; fishermen losing income because of sedimentation in rivers and lakes; road users delayed when road embankments or structures collapse. The cost of correcting these problems are often many times greater than the costs of simple preventative measures.

**Impacts**

**Erosion**
When natural conditions are modified by the construction of a road, it marks the start of a race between the appearance of erosion and the growth of vegetation. Erosion problems can result from diverse causes and are the consequence of constant interaction between soil structures, climatic conditions, and water resources. In some cases erosion might result in consequences far beyond the road itself, affecting slopes, streams, rivers, and dams at some distance from the initial cause.

**Stability of slopes**
Slope stability can be disturbed during the construction of road cuttings or embankments. Steepness of cut slopes, deficiency of drainage, and modification of water flows can result in landslides. Some sensitive soils, such as shale, are known for being unstable and difficult to drain.

**Side-tipping of spoil material**
Spoil material from road cuttings can kill indigenous vegetation and add to erosion and slope stability problems. Large amounts of spoil can be generated during construction in mountainous terrain. It is sometimes difficult to design for a balance between cut and fill volumes of earth at each location, and haulage to disposal sites may be expensive. This creates a need for environmental management of tipped material.

**Excessive water flows**
These flows can arise from blocked ditches and damaged water control structures. They are discussed further in the following chapter.

**Contamination of soil**
Soil contamination can arise from daily traffic operation on very busy roads (typically over 20,000 vehicles per day). Metals such as chromium, lead, and zinc remain in the soil for hundreds of years. These effects are generally very localized; for example, a highway open to traffic for the past 25 years reaches the limits of toxicity over a width of less than 10 meters and metal pollutants can no longer be distinguished from subsoil pollution as of 50 to 100 meters from the road, as shown in figure 7.1. Soil contamination risks also arise from transportation of hazardous products during road construction and subsequent traffic operations. These are discussed further in chapters 18 and 20.

**Chain impacts**
Chain impacts involving soil damage may affect many aspects of the environment. For example, creation of a road could encourage bush fires and deforestation, which in turn could lead to erosion of bare slopes, rechanneling of rivers and streams, and possibly minor landslides and changes in microclimate.

**Impact identification and assessment**
In order to identify potential problems of soil erosion or slope stability, consider the following:

- Evidence of soil problems on previous or similar works can be a useful indicator. What types of erosion are present? How advanced and how large an area do they cover?
- Problems are most likely to arise where (a) water flows are more concentrated than be-
fore the existence of the road project, (b) cleared areas are left unplanted, or (c) cut or fill slopes are steeper than previous natural slopes.

- Where there are indications of potential problems, more detailed assessments can be assisted by walking the site with road engineers and natural scientists.
- Dialogue with the local population is a vital part of assessing existing and imminent erosion problems. Adapting local erosion control techniques used in agriculture can be helpful to the road agency, as can learning the most suitable plant varieties for controlling erosion in the area.
- More detailed data collection can then be undertaken where necessary to establish the sensitivity of the study area to erosion problems and the extent of impact areas which need to be evaluated.

Much of the information necessary for this identification can be obtained from maps (geological, hydrological, and topographic) and aerial photographs, which are discussed in some detail in part III of this handbook. These may be complemented by site observations, for example of signs of erosion or soil instability, major flooding, and agricultural practices.

**Mitigation measures**

**Avoidance**

The extent of environmental impacts of road projects on the soil can be reduced by:

- Reducing the area of ground clearance
- Prompt replanting and plant maintenance
- Avoiding sensitive alignments
- Controlling the speed and volume of water flows.

**Mitigation**

There are a wide range of techniques designed to reduce the risk of damaging the soil and to fit the project into its environment with few adverse effects. Simple techniques such as replanting will be effective in many situations. More sophisticated techniques, such as retaining walls, are used only in the most difficult cases.

**Replanting**

Replanting cleared areas and slopes is the most important action to reduce erosion and stability problems. This should be undertaken as early as possible in the construction process, and before erosion becomes too advanced. Vegetation should be selected to serve a specific engineering function. In some cases

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**Figure 7.1 Pollution levels found in roadside soil and plants**

![Figure 7.1 Pollution levels found in roadside soil and plants](image)

** Soil analysis **

<table>
<thead>
<tr>
<th>Points</th>
<th>Cd in ppm</th>
<th>Pb in ppm</th>
<th>Na in ppm</th>
<th>Hydrocarbons in mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.36</td>
<td>128.6</td>
<td>7.50</td>
<td>1.15</td>
</tr>
<tr>
<td>2</td>
<td>&lt;0.05</td>
<td>117.3</td>
<td>7.50</td>
<td>1.10</td>
</tr>
<tr>
<td>3</td>
<td>&lt;0.05</td>
<td>49.3</td>
<td>7.50</td>
<td>0.35</td>
</tr>
<tr>
<td>4</td>
<td>&lt;0.05</td>
<td>167.4</td>
<td>12.50</td>
<td>0.25</td>
</tr>
<tr>
<td>5</td>
<td>&lt;0.05</td>
<td>95.2</td>
<td>11.25</td>
<td>0.70</td>
</tr>
<tr>
<td>6</td>
<td>&lt;0.5</td>
<td>37.3</td>
<td>11.25</td>
<td>0.15</td>
</tr>
</tbody>
</table>

** Plant life analysis **

<table>
<thead>
<tr>
<th>Cd in ppm</th>
<th>Pb in ppm</th>
<th>Hydrocarbons in mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>7.0</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>0.8</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>0.6</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>15.2</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>&lt;0.1</td>
<td>&lt;0.5</td>
<td>0.8</td>
</tr>
</tbody>
</table>
a short-lived engineering structure, such as a woven wattle fence, is installed, along with vegetation which can take over the function of the structure in time. Engineering functions of vegetation include its abilities to:

- Retain material moving over the surface (stems)
- Armor the surface against erosion and abrasion (roots, and leaves, by interception of raindrops)
- Support the slope by propping from the base (tree and shrub boles and roots)
- Reinforce soil by increasing its shear resistance (roots)
- Drain soil profile by taking water into the soil (roots). This can increase ground water pressure.

Grasses (or herbaceous plants) essentially limit surface erosion. In order for sowing to be successful, it is necessary to:

- Store and reuse topsoil. This requires that arable soil should be separated from subsoil during work execution. The more fertile arable soil can then be deposited on the slopes to form a superficial layer.

- Choose the right varieties, and whenever possible, use local varieties. Vetiver grass, (*Vetivera zizanioides*), is also an effective variety for protecting against soil erosion (box 7.1).
- Choose the right time of the year (for example, take advantage of the rainy season).
- Identify the type of soil to be replanted.

Sowing can be performed manually or mechanically, for example with farm machinery (figure 7.2). Hydroseeders (which use solutions of water, fertilizer, binder, and seeds) are of interest in areas where access is difficult, or as a labor-saving practice where labor costs are high. Other products can also be applied to compensate for sterile soil and to promote seed germination. This includes mulch to protect the seed, covers, binders, and soil stabilizers.

Shrubs and trees (ligneous or woody plants) control erosion on slopes that are generally steeper, for example, over 30 to 40 percent. Examples are shown in figure 7.3.

**Slope protection**

Stabilizing slopes to control erosion requires the proper engineering design of the form, in-

---

**BOX 7.1 Vetiver grass**

*Vetiver grass* is receiving growing international attention for its special properties in stabilizing slopes and resisting soil erosion. Its roots can be as deep as 3 meters below the surface, probing into rock fissures and tying soil layers firmly to their base and resisting slope slippage. The leaves and stems have a remarkable ability to slow water flows and trap sediment, creating a terracing effect on slopes and preventing siltation of creeks and drains.

*Vetiver grass* is typically planted as a hedge and will not spread to crowd out other plant life. It can be grown in a wide range of climates, from heavy rainfall to low-rain areas, and can survive fires and long droughts. It is not, however, suitable for freezing conditions.

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**Figure 7.2 Simple techniques to improve the success of seeding on moderate slopes**

- Notching
- Blazing
- Pocking

---
cline, and drainage. Slope retaining techniques are necessary when:
- Slopes are unstable because they are too high and steep
- There is a risk of internal erosion or localized rupture because of drainage difficulties
- It is necessary to decrease the amount of earth work because the road width is limited.

Well-established techniques for slope protection include:
- Intercepting ditches at the top and bottom of slopes. Gutters and spillways are used to control the flow of water down a slope
- Terraced or stepped slopes to reduce the height of a slope. A berm (or risberm) is the level section in between slope faces (figure 7.4)

Figure 7.3 Ligneous plant protection of slopes (labor-based techniques)

- Riprap, or rock material embedded in a slope face, sometimes with planting (figure 7.5)
- Retaining structures: examples include gabions (rectangular wire “baskets” of rocks), cribs (interlocking grid of wood or concrete beams, filled with earth or rock), or other types of wooden barricades and gridwork, usually battered back against the slope
- Retaining walls: more substantial engineering structures able to resist bending, and with a footing designed to withstand pressures at the base of the slope
- Reinforced earth: embankment walls built up as the earth fill is placed, with anchors compacted into the fill material
- Shotcreting and geotextiles (figure 7.6):
Figure 7.4 Examples of combined techniques for slope protection

Planting over riprap

Soil and gravel
Deep-rooted plants
Rocks
Pavement

Figure 7.5 Standard detail of rock facing on a slope

Roadway surface
Ground line
Double row may be required at bottom

Figure 7.6 Some applications of geotextiles

Rectification of alignments over compressible soil
Road subgrades
Erosion protection

Decrease in amount of earthwork
Preserves the sub-base from any contamination (proximity of groundwater)
Acts as filter by retaining the finest particles
generally more expensive options with specific applications.

Table 7.1 presents indicative comparisons of some of these alternatives. Particular problems associated with drifting sand in desert areas are discussed in box 7.2.

**Drainage**

A major factor in the prevention of soil erosion and siltation of watercourses is the control of the quantity, location, and speed of water flows in the vicinity of exposed soils and slopes. Some important techniques include:

- Cutoff drains to catch water before it reaches critical areas, and diverging drains to divert water away from drains so that flows do not become too large
- Natural materials for energy dissipation in drains, including various combinations of sticks, hay bales, rocks, and plantings. Some of these require ongoing maintenance
- Concrete dissipation structures designed to slow fast-running stormwater in drains, and hence reduce downstream erosion
- Settlement basins: these allow silt, pollutants and road rubbish to settle out of runoff water before it flows into downstream watercourses. These are discussed further in the following chapter of this handbook.

### Table 7.1

**Indicative comparison of various erosion mitigation measures**

<table>
<thead>
<tr>
<th>Measures</th>
<th>Effectiveness</th>
<th>Comparative costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stepped slopes</td>
<td>High</td>
<td>Substantially raises the volume of earthworks depending on the distance from quarries</td>
</tr>
<tr>
<td>Riprap</td>
<td>High for embankment protection</td>
<td></td>
</tr>
<tr>
<td>Grass seeding</td>
<td>Only surface effective, avoids start of erosion</td>
<td></td>
</tr>
<tr>
<td>Shrubs</td>
<td>High—even in depth after several years' growth only</td>
<td>2 to 3 times cost of grass</td>
</tr>
<tr>
<td>Crib walls</td>
<td>Good</td>
<td>One-quarter the cost of a retaining wall</td>
</tr>
<tr>
<td>Geotextiles</td>
<td>High; good mechanical and chemical resistance</td>
<td>10 to 20 times the cost of vegetation</td>
</tr>
<tr>
<td>Gridwork, wooden barricades, etc.</td>
<td>Fairly good</td>
<td>5 times the cost of vegetation</td>
</tr>
</tbody>
</table>

### Box 7.2

**Control of sand encroachment on roads—Mauritania**

For many countries and regions, specific measures and procedures are needed to deal with particular local environmental concerns. An example is the problem of sand encroachment onto roads in desert areas.

Research was undertaken to understand the patterns of dune formation and sand movement, and to develop protective measures for the road which were more in harmony with environmental patterns, rather than simply resisting them. Guidelines were then developed for encouraging dune development upwind of a road, stabilizing existing dunes, and reforesting dunes in higher rainfall areas with local tree species. The measures often require ongoing maintenance and attention.

**Compensation**

Typical compensation measures for soil negatively affected by road projects include reconstitution of land form to follow the slope line and development of spoiled agricultural land into other activities, such as transformation of a quarry into a lake for fish breeding.

**Environmental study checklist**

- **Baseline data** should identify the sensitivity of the road and surrounding areas of the proposed works to forms of erosion and instability; it should also identify the area of study necessary to assess impacts.
- **Route choice** should avoid areas with a high risk of erosion or slope instability where feasible.
- **Analysis of alternatives** for limiting erosion should give priority to measures that are easy to implement and require only local material, giving consideration to: form and incline of slopes; design of the drainage network; re-planting methods and schedule; and ease of future maintenance.

- **Mitigation plans** should include measures to maintain and repair soil-protection planting and other works.
- **Environmental specifications for contractors** should include road design of vertical alignment, cross-section, drainage, stabilization, and worksite details such as quarry design and construction traffic.
- **Legislation dealing with soil conservation** should be considered, including limits on land use along the road (for example, restrictions on fruit and vegetable farming) and requirements for erosion control, especially in mountainous regions.

**Bibliography**


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Department of Public Works and Highways, Report No. 66, Republic of the Philippines, Manila.


Water

KEY POINTS

■ Drainage should be designed and maintained to protect the road and adjacent slopes. One of the aims of environmental assessment should be to ensure that this drainage system is also compatible with the surrounding environment.

■ Roads can contribute to changes in the flow and quality of surface water and groundwater, sometimes leading to increased flooding, erosion, siltation, or drying up of natural groundwater levels. These changes in turn can have substantial effects on natural vegetation and wildlife, and on human activities.

■ Impacts on the water system can extend well beyond the immediate vicinity of the road, and apparently small problems can sometimes have larger consequences.

■ Well-designed road works can also improve the surrounding environment by retaining water for human or natural benefits, or by reducing flooding and draining of unhealthy standing water.

■ Sensitive areas should be mapped for the consideration of alternative routes and the location of major structures.

KEY WORDS: Water flow, groundwater, flooding, siltation, erosion, drainage, pollution
Impacts
Road development can lead to three types of modification to the natural water environment.

Modifications to the flow of surface water
Roads modify the natural flow of surface water by concentrating flows at certain points and, in many cases, increasing the speed of flow, as illustrated in figure 8.1. Depending on local conditions, these changes can contribute to flooding, soil erosion, and siltation of streams. These effects can often be felt well beyond the immediate vicinity of the road. Paving a road reduces the permeability of the soil, increasing water runoff.

Modifications to the flow of groundwater
Road drainage and excavation can lower the water table in surrounding areas, while embankments and structures can raise the water table by restricting flow. Two examples are shown in figure 8.2. The effects can include erosion, deterioration of soil and vegetation, loss of water for drinking and agricultural use, and impacts on fish and wildlife.

Impacts on water quality
Sedimentation, changes in biological activity in streams and their banks, uncontrolled construction activities, and spills of chemicals and pollutants can all have adverse effects on roadside water quality. Long-term pollution from exhaust emissions, pavement and tire wear, and corrosion of metals may be issues on some very busy roads in urban areas. Seasonal pollution issues arise during salting of roads for winter maintenance and during periods of low stream flow. Impacts of road works and accidental spills are discussed in later sections.

Impact identification and assessment

Water flows
Expected surface water flows and speeds should be calculated and compared to drainage standards, and consideration should be given to the sensitivity of soils and vegetation and to past experiences with erosion in similar situations. Effects should be considered as far downstream as the higher flows and increased speeds are significant. These factors are considered in drainage design of road pavements but should be checked in an environmental assessment.

Changes in the water table
Changes in the water table should be considered where ground water is important for human or agricultural uses and in dry regions where ground water is important to natural flora and fauna. The use of the road drainage system to retain more water in dry areas or take away unhealthy standing water are potential positive environmental benefits of road development.

Hydraulic characteristics to be measured include speed, flow, level, and turbidity (the presence of suspended particles). Where required, further basic data on boundaries of floodable zones, variations in water depth in wells and makeup of riverbeds can be obtained from responsible government agencies and local residents.

Where substantial changes in water flow are expected, the dynamics of the hydrographic network should be analyzed carefully, as there are sometimes extensive chain reactions (figure 8.3).
Water pollution

Water pollution problems generally arise on roads with high traffic flows and should also be considered for projects:

- Near a drinking water intake point (see figure 8.4)
- Bordering areas of great biological value
- Near a river with a low minimum flow
- Crossing soils with limited filtering power. Limestone and karsitic dolomite, for example, have zero filtering power, while sand and sandstone actively filter suspended matter, and clays greatly limit pollution effects.

Parameters used to measure water quality include: organoleptic (such as color, odor); physical and chemical (such as turbidity, conductivity, sulfates, aluminum); undesirable substances (such as nitrates, hydrocarbons); toxic substances (such as chromium, lead, pesticides); and microbiological (such as total coliforms, streptococci). It is customary for water quality to be classified according to the least favorable parameter measured. Polluting discharge for a road project can be assessed either by heavy metal content or suspended matter, whichever is the least restrictive (table 8.1).

Sensitivity of a study area may be established from interactions between the road project and the environment, taking account of project route alternatives and traffic projections, and environmental data on:

- Surface water: water flow, discharge, floodable zones, low water level
- Groundwater: size of water table, direction of flow, vulnerability
- Soil characteristics: degree of permeability, filtration
- Water utilization: drinking water, agriculture, fish breeding
- Problems with the physical and chemical quality of water.

Sensitive areas should be mapped for the consideration of alternative routes. Sensitivity to changes in water flows may be physical (effects on hydrology), biological (habitat

<table>
<thead>
<tr>
<th>Pollutant deposits from road traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 veh/day</td>
</tr>
<tr>
<td>Dust: kg/day/km</td>
</tr>
<tr>
<td>Lead: gm/day/km</td>
</tr>
<tr>
<td>Zinc: gm/day/km</td>
</tr>
<tr>
<td>Hydrocarbons: kg/day/km</td>
</tr>
</tbody>
</table>

Note: Typical quantities deposited on the pavement in Western European countries. Actual values vary with vehicle maintenance, road conditions, and loads carried.

Figure 8.2 Modifications in water table linked to road construction

1. A fill road that causes a drop in the water table downstream (in black on the drawing)

2. A cut road that lowers the water table. Ground cover disappears in second phase.
of fauna and living species), and human (water for recreation, economic and domestic uses).

**Mitigation measures**

**Avoidance**
Impacts can be avoided if no significant changes are made to existing water flows in the vicinity of the road.

**Mitigation**
Water speed reduction measures can substantially reduce potential impacts. Examples include grasses, riprap, and other devices in water channels and dispersion structures in main drains (see previous chapter on soil and erosion). Route selection and the location of major structures can attempt to fit the road into less sensitive areas.

Settlement basins are sometimes used to remove silt, pollutants, and debris from road runoff water before it is discharged to adjacent streams or rivers. They are most appropriate where the downstream environment is particularly sensitive or where the levels of silt or pollutants are particularly high (figure 8.5). *Oxidating macrophytes* can be used to naturally remove some pollutants. Ongoing maintenance may be required where large amounts of silt are deposited.

Infiltration ditches can be used to reduce the flow of pollutants (figure 8.6). Water collection, control, and treatment equipment is a more expensive option for polluted runoff from pavements and slopes.

A variety of mitigation measures are compared in table 8.2.

---

**Figure 8.3 Illustration of chain reaction impact**

1. Regressive erosion in excavated areas
2. Undermining of highway structure foundations
3. Drop in water table downstream
4. Decrease in farming areas downstream from the structure
5. Degradation of vegetation upstream due to regressive erosion
6. Increase in water turbidity
7. Deposit of sediment in calm zones
8. Modification in vegetation due to a lower water table

---

**Figure 8.4 Assessment of pollution near sensitive points**

- Drainage
- Water table
- Spread of pollution
- Pumping station
- Polluted intake

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*ROADS AND THE ENVIRONMENT: A HANDBOOK*
Figure 8.5 Progression in water treatment

Solution 1 and 2: Not very sensitive environment
Solution 3: Sensitive environment
Solution 4: Highly sensitive environment
Solution 4 requires management of the road. The settling basins must be cleaned out at regular intervals. The sludge collected contains high levels of heavy metals and should be stockpiled or processed.

Solution 1: Direct evacuation of water from pavement

Solution 2: Lining ditches with grass to provide initial filtration

Solution 3: More complete filtration using macrophytes

Solution 4: Combination of various treatments for advanced filtration: waterproofing of subgrade, oil removing, settling basin macrophytic lagoonning
**Environmental enhancement**

Road projects often provide an opportunity to improve some aspects of the water environment (box 8.1):

- In very dry areas, road drainage can be designed to retain water in small dams or maintain a high water table—for example, by raising the inlets to drainage culverts—increasing the availability of drinking water and the viability of many species of flora and fauna.
- In areas prone to flooding, road works can either incorporate retarding basins which reduce runoff peaks (and potentially save on drainage structures), or they can improve

<table>
<thead>
<tr>
<th>Measure</th>
<th>Effectiveness</th>
<th>Comparative costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flow limitation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercepting ditch</td>
<td>Highly effective if properly</td>
<td>Economical: cost of an earthen ditch</td>
</tr>
<tr>
<td></td>
<td>maintained</td>
<td></td>
</tr>
<tr>
<td>Cascade flow slowdown unit</td>
<td>Good but perpetuates flow linearity</td>
<td>Negligible for a concreted ditch</td>
</tr>
<tr>
<td>(dissipator)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood basin</td>
<td>Very good if properly situated</td>
<td>100 times the cost of an outfall</td>
</tr>
<tr>
<td><strong>Pollution limitation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct drainage</td>
<td>For very limited volumes according</td>
<td>Equivalent to cost of an earthen ditch</td>
</tr>
<tr>
<td></td>
<td>to outlet</td>
<td></td>
</tr>
<tr>
<td>Grass</td>
<td>For limited volumes</td>
<td>Equivalent to fascine work combined</td>
</tr>
<tr>
<td></td>
<td></td>
<td>with grass seeding</td>
</tr>
<tr>
<td>Oxidating macrophytes</td>
<td>For long retention periods</td>
<td>20 times the cost of an outfall</td>
</tr>
<tr>
<td>Settling basin</td>
<td>Highly effective if maintained,</td>
<td>200 times the cost of an outfall</td>
</tr>
<tr>
<td></td>
<td>requires space</td>
<td></td>
</tr>
</tbody>
</table>

**BOX 8.1**

**Environmental enhancements in road projects in Africa**

**Sahelian Region**

Many small dams storing seasonal rainfall were built in the Sahel to fight drought. Additional water storage can be created through the replacement of a bridge or box culvert by a spillway or a raised structure to accumulate water upstream from the road. This makes it possible to reduce construction costs for the road and, at the same time, to store water for the local population. Where standing water is unhealthy or attracts mosquitoes, water management techniques can improve drainage and absorption. A number of specific design alternatives are described by Lantran (1993).

**Burkina Faso**

The rehabilitation of 275 km of rural road in southwest Burkina Faso included provision of 20 percent of the $40 million budget for construction wells to be retained for permanent village use, along with dam construction, land drainage, terracing for rice fields, and tree planting set back from the road. Water retention along road embankments was achieved by high placement of cross-culverts, and borrow pits were landscaped for running-water ponds and other uses. Villagers began working on the improved roadside fields and positive impacts on local agriculture were experienced even before roadworks were complete.

Source: Baillon et al. 1994; SETRA; Canadian International Development Agency.
drainage in residential or farming areas which are excessively sensitive to flood damage. In some cases a section of the road itself can be constructed as a dam, perhaps designed to operate as a spillway during peak floods.

- Drainage of unhealthy standing water can often be improved as part of road improvement projects.

**Compensation**
Compensatory measures should be considered if they prove more cost-effective than mitigation, or if mitigation proves impossible. Examples are:
- Moving a bore hole, if the ground water permits
- Incorporating environmental enhancements in the project.

**Environmental study checklist**
- **Baseline data and potential environmental impacts:** Identify the main problems and the sensitivity of the study zone, working from basic data on the catchment basin, nature and frequency of flooding, water quality, water use, fauna species and habitats. Assess likely modification of baseline conditions arising from the project.
- **Analysis of alternatives:** This should take account of design changes which concentrate or speed up water flows, lower the water table, or increase flood risks. Factors to be considered include horizontal and vertical alignment, cross section, slopes, drainage of subgrade and surrounding area, and restoration of natural surface and underground flow.
- **Mitigation plan** should include proposals for specific technical measures, such as plant-

---

**Figure 8.6 Other mitigation measures**

- **Infiltration ditch**
- **Laying of a geotextile to form a layer of contamination protection in a zone subject to strong variations in groundwater**
ing of cleared areas and flow-speed dissipators in drains, and recommendations for subsequent maintenance.

- **Environmental specifications for contractors** should cover road design, drainage installation, and worksite plans which may affect water flows and quality.

- **Legislation and regulations** should be considered, as they affect drinking water intakes, possibly with the definition of protection perimeters; constructions in floodable zones; and discharge capable of changing the quality of surface water or ground water.

**Bibliography**


Air quality

KEY POINTS

- Air pollution from road traffic arises mainly from vehicle engine and exhaust emissions and dust.

- Local effects are those in the immediate vicinity of a road. Local air pollution can affect the health of those living and working near the road, as well as soils, crops, water, and facades of buildings. This is mainly of concern in areas of high population density.

- Local pollution can be influenced by the design and operation of specific road sections. However, specific attention is generally required only for roads in large cities with heavy traffic.

- Alternative routes, traffic management, speed control, and planting can be used to mitigate negative impacts on air quality.

- Global or regional effects of air pollution—for example, the greenhouse effect, destruction of the ozone layer, and acid rain—can generally only be reduced through national or regional transport policies and regulations affecting vehicle and fuel standards, vehicle maintenance and testing, and demand management and road use pricing. These effects are not usually considered in the evaluation of specific road projects and are only briefly discussed in this handbook.

- In many countries, the public health problems arising from motor vehicle air pollution are not as large as those due to water pollution or road accidents. As a result, traffic emissions are seen as a high priority issue only in a limited number of large cities in certain countries. However, air pollution problems are expected to increase with increasing population and motorization.

KEY TERMS: Pollution, emissions, greenhouse, ozone, acid rain, health, local, global, vehicles, fuels, demand management
The emission of pollutants by vehicles has worldwide impacts. Pollution from certain components involved in transportation contributes greatly to the atmospheric pollution generated by man. Reduction of these effects requires changes in national policies, such as setting standards, and use of other modes of transportation and other sources of energy. In this section, atmospheric pollution created by motor vehicles will primarily be considered on a local level and for specific road projects. The individual use of cars is responsible for 60 percent of carbon monoxide emissions, 60 percent of hydrocarbon emissions, and more than one-third of the nitrogen released into the atmosphere.

**Impacts**

Air pollution caused by vehicles follows a cycle, as illustrated in figure 9.1: emission of pollutants (depending on type of vehicle, type of engine, engine maintenance, and fuel quality); propagation in the air (depending on the local topography, temperature, rainfall, and wind); and reception by humans, soil, fauna, and flora.

The main pollutants and impacts are:

- **Nitrogen oxides** (NOx), which can remain in the atmosphere several days and play a major role in the formation of acids in the atmosphere. It affects human respiration and plants (either as an acid or as an oxidant).
- **Hydrocarbons** (HC), are created by the incomplete combustion of fuel and by its evaporation. They include a wide variety of organic chemical substances. They have multiple effects on health: toxic, irritant, carcinogenic or mutagenic.
- **Carbon monoxide** (CO), remains in the atmosphere from one to two months. It combines with hemoglobin in human blood and prevents it from conveying oxygen. In small doses, it can cause headaches, vertigo, and sensorial disorders; in strong doses, asphyxiation can prove mortal. Diesel engines cause far less emissions of both CO and HC than gasoline engines.
- **Sulphur dioxide** (SO2), which can remain in the atmosphere from a few hours to several weeks. The emission rate is directly linked to the sulphur contained in the fuel. It aggravates respiratory problems and its acidity attacks plants (acid rain), aquatic life, and materials.
- **Particulate matter**, including suspended airborne particles from diesel fuel, materials produced by friction, tire wear, heavy metals, and dust. Health effects of these particles may include eye and respiratory irritation, and fibrotic, allergenic, carcinogenic or mutagenic effects.
- **Lead** (Pb), added to fuel to raise the octane rate and help lubricate the engine, has well-known effects on health. Examples are ner-
vous disorders (especially in children) and anemia. Lead emitted into the air can be breathed in directly or consumed through drinking water or vegetables.

Other pollutants include benzene, carbon dioxide (CO₂), and chlorofluorocarbons (CFCs). These primary pollutants are then transformed into secondary and tertiary pollutants such as ozone and acid rain (see figure 9.2) through various chemical reactions linked to meteorological factors, air temperature and humidity, and the topography of the site.

Impacts of specific pollutants can be roughly grouped as follows: greenhouse effect (CO₂), hole in the ozone layer (CO, HC, NOx, CFCs), acid rain (HC, NOx, SO₂), health (CO₂, CO, HC, NOx, SO₂, lead, CFCs, benzene).

**Impact identification and assessment**

Air pollution from road traffic should be considered in environmental assessments of specific projects where current air pollution levels begin to approach or exceed international air quality standards and where motor vehicles are a major source of the problem.

Pollution from industrial activity, especially coal-fired plants, should also be considered. In some cases this may be a more important pollution source, while in other cases the cumulative effects of traffic and industrial pollution may need to be addressed.

The degree of pollution may be determined by such measures as:

- Mean annual emissions per type of pollutant (NOx, SO₂, SOx, etc.)
- The daily value exceeded once a year per type of pollutant
- Hourly concentration peaks.

The assessment should identify locations where pollutants might exceed acceptable levels, the types of pollutant of greatest concern, and the approximate contribution of industrial activities. Where this initial analysis indicates a potential problem, further investigations may be required.

Measurement of pollution along roads is based on traffic classifiers (for vehicle numbers, types, and speeds), meteorology stations (for wind, temperature, and air humidity effects on dispersion), and exhaust gas analyzers. The latter include:

- CO by infrared absorption units or ecolyzers
- Hydrocarbons by flame photoionization units
- NOx by chemiluminescence
- Dust and particulate matter by beta gage (passage through β-ray), by aspiration (deposit on filter, weighing), and by gravity (deposit on lubricated panel).

Dispersion models (see part III) can be

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**Figure 9.2** Simplified diagram of interactions between various air pollutants
used to predict the pollutant level reached after project completion. These models take account of such factors as atmospheric conditions, traffic, and the presence of buildings.

The causes of pollution within the traffic stream should also be clearly identified, since these have a large effect on the choice of mitigation strategy. It is important to determine whether pollution arises mainly from gasoline or diesel vehicles, whether it can be traced largely to a specific vehicle type (such as buses in Santiago or motorcycles in Bangkok), and whether it is produced by all vehicles of a given type or disproportionately from a small percentage of badly-maintained vehicles.

The health impacts of motor vehicle air pollution are difficult to quantify and, hence, difficult to value in economic terms. The bibliography provides further information on the types of health problems which have been linked with urban air quality.

**Mitigation measures**

**Avoidance**
Impacts of motor vehicle air pollution can be avoided to some extent by routing traffic away from populated areas and reducing traffic growth.

**Mitigation**
National or regional measures related to air pollution may form part of an environmental action plan or an air quality strategy for a major city. Measures could include policies, regulations, charges, and enforcement programs covering:

- Vehicle emissions standards and inspection and maintenance requirements
- Retiring or retrofitting high-use and high-polluting urban vehicles
- Fuel technology and quality
- Pricing of motor vehicle purchase and use

<table>
<thead>
<tr>
<th>TABLE 9.1</th>
<th>Indicative comparison of various air pollution mitigation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures</td>
<td>Effectiveness</td>
</tr>
<tr>
<td>Vehicle emissions control and maintenance</td>
<td>Reduces emissions of vehicles on the road</td>
</tr>
<tr>
<td>Traffic management</td>
<td>Optimizes speed and flow to reduce emissions</td>
</tr>
<tr>
<td>Demand management</td>
<td>Reduces growth of traffic</td>
</tr>
<tr>
<td>Vegetation screens</td>
<td>50 percent retention of particles for a width of 15 to 20 meters using resistant species including evergreens</td>
</tr>
</tbody>
</table>

**Figure 9.3 Screen of vegetation**
Filtering role of vegetation

< 10-20 m >
• Management of demand for motor vehicle travel and availability of alternative modes
• Management of traffic efficiency.

Project-specific measures to limit motor vehicle air pollution impacts include:
• Selection of road location, alignment, capacity and geometric standard
• Traffic management measures
• Use of vegetation to filter some dust and particulate matter created by road use (figure 9.3)
• Sealing dirt roads to suppress dust in polluted urban areas.

Some of these options are compared in table 9.1.

Compensation
No compensatory system is used at present.

Environmental study checklist
• Baseline data and potential environmental impacts: information on current and projected levels of various pollutants and on the site’s sensitivity, which depends on population density, industrial activity, traffic levels, and exposed people living and working close to the roadside. For potentially sensitive sites, further information may be needed on major sources of vehicle pollution and air pollution dispersion patterns.
• Analysis of alternatives: could include routes that avoid sensitive areas and designs which promote efficient traffic flow. Consideration may also be given to options which minimize traffic growth in congested urban areas.
• Mitigation plan: project-level measures may include design changes, traffic control, and planting vegetation. Many of the factors affecting motor vehicle air pollution can only be addressed through broader policies and regulations.
• Environmental specifications for contractors: mainly concern specific work such as traffic management schemes and vegetation screens.
• Legislation and regulations are an important component of an integrated air quality strategy; they should in time address emissions standards of new and in-use vehicles, vehicle inspection and maintenance requirements, and fuel quality.

Bibliography
Natural environment: fauna and flora

KEY POINTS

- Road projects can have significant effects on natural plant, animal, and aquatic life.
- These effects can take many forms. Where they occur, it may be important to take account of indirect effects and consider the consequences for the complete ecosystem.
- Route choice should take account of environmental concerns.
- Solutions adopted early in project planning are generally the least expensive, while those adopted in later phases of the project can be expensive and time consuming.
- Construction impacts are especially important and require special attention.

KEY WORDS: Ecosystem, habitat, biodiversity, migration, displacement
The term "natural environment" is used here to refer to the flora and fauna, or, in simple terms, plant and animal life. Other basic components of the physical environment are covered elsewhere in this handbook.

**Impacts**

**Direct impacts**
- **Consumption of natural space.** In addition to the road itself, borrow sites and material stockpiling areas, accesses and quarries can disturb the natural environment.
- **Severance.** When a road cuts through a forest, the sum of the two parts created by the cut is less than the value of the initial whole. The road isolates the animal and plant populations living on either side of the right of way. If a population is too limited in number, it could become extinct in this area, and the ecological wealth of the forest environment would diminish. Severance effects can restrict access of some animals to their usual zones of reproduction or seasonal feeding. On busy roads, the death rate for crossing amphibians or other slow-moving animals can be as high as one in ten.
- **Accessibility.** Roads bring human activities closer to natural flora and fauna. In many cases, indirect impacts are more damaging, and their effects can be felt farther, sometimes several dozen kilometers from the road. Where the road provides access to areas which were previously relatively untouched by human activities, the environmental assessment should encompass the entire area for which these effects are predicted. For example, the creation of a road may lead to new dwellings and even villages being built along the route. This leads to further land being cleared for agriculture, the cutting of firewood, clearing of forests, and the development of new public spaces and social infrastructure.

**Indirect impacts**
These are experienced by fauna, flora, water, soil, and other components of the natural environment:
- Plants and animals, due to disturbances in the flow of surface water and the level of the water table. In extreme cases, this can lead to loss of vegetation, followed by erosion (figure 10.1)
- Aquatic life, due to the rechanneling of a waterway, or an increase in suspended sediment
- Trees on the perimeter of a forest, due to an increase in exposure to sunlight or wind
- Vegetation and soil, due to fires, increased human activity, and emission of pollutants by vehicles
- Vegetation and animals, due to dissemination of diseases by vehicles and people.

**Effects on different types of environment**

**Forest ecosystems** are characterized by a wealth of flora and fauna, and by strong interaction between the components of the system. Consequently, impacts will be high. They are described further in table 10.1.

---

**Figure 10.1 Potential impacts of lowering the water table**
The creation of a road initially results in a decline in vegetation, followed by erosion.
Open ecosystems include grass and tree savannas, steppes, and prairies, ranging from desert zones to semiwooded zones. These ecosystems function differently from the preceding ones, as there is less interaction between the components. Impacts are relatively less pronounced than in the preceding case.

Humid ecosystems, such as mangroves, ponds, and marshes (table 10.2) are characterized by a great wealth of flora and fauna and by high productivity. In general, these ecosystems are of great importance to catchment basins because of their role in regulating the flow of waterways, filtering water, migration of birds, and economic uses. These environments have regressed sharply over the last few decades and now merit important protective measures.

Other ecosystems, are summarized in table 10.3. Successive stages in the development of an ecosystem are shown in figure 10.3.

**Impact identification and assessment**

An initial assessment of potential environmental impacts should commence with a brief evaluation of the flora and fauna along the route, including such questions as:

**TABLE 10.1**

<table>
<thead>
<tr>
<th>Forest ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct impacts</strong></td>
</tr>
<tr>
<td>Physical road right of way—consumption of natural space (a few hectares per kilometer of road), severance effects on fauna</td>
</tr>
<tr>
<td>Road traffic—animal mortality due to collision (limited visibility)</td>
</tr>
<tr>
<td><strong>Indirect impacts</strong></td>
</tr>
<tr>
<td>Penetration route leading to subsequent clearing, the creation of secondary roads, deforestation, poaching, agriculture, breeding</td>
</tr>
<tr>
<td>Border effect linked to the sharp increase in exposure to light and modified atmospheric factors</td>
</tr>
<tr>
<td>Effects of ecological systems—disturbance of surface water flow, erosion, modification in biodiversity and especially a decrease in large species requiring extensive territories. Modification in climatic regulation exerted by major forests</td>
</tr>
<tr>
<td>Dissemination of disease</td>
</tr>
</tbody>
</table>

**TABLE 10.2**

<table>
<thead>
<tr>
<th>Humid ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct impacts</strong></td>
</tr>
<tr>
<td>Physical road right of way: consumption of natural space, especially on embankments, severance effect with reduction in the exchange of water and matter</td>
</tr>
<tr>
<td>Risk of long-term or accidental pollution</td>
</tr>
<tr>
<td><strong>Indirect impacts</strong></td>
</tr>
<tr>
<td>Penetration route leading to drainage operations and subsequent agriculture</td>
</tr>
<tr>
<td>Modification of flow and level of water table often followed by an evolution in vegetation, and a possible loss of productivity</td>
</tr>
</tbody>
</table>

**TABLE 10.3**

<table>
<thead>
<tr>
<th>Other ecosystems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System</strong></td>
</tr>
<tr>
<td>Island ecosystems</td>
</tr>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Numerous indigenous flora and fauna species (present in one location only)</td>
</tr>
<tr>
<td>Great fragility of these environments</td>
</tr>
<tr>
<td>Impacts</td>
</tr>
<tr>
<td>Risk of plant or animal species disappearing</td>
</tr>
<tr>
<td>Addition of new species (domesticated or not) destroys the balance of ecological systems</td>
</tr>
<tr>
<td>Mountain ecosystems</td>
</tr>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Numerous endemic species, mountain environments can be assimilated with island environments</td>
</tr>
<tr>
<td>Generally high rainfall and importance of water flow problem</td>
</tr>
<tr>
<td>Impacts</td>
</tr>
<tr>
<td>Major earth work, need to take cut-and-fill volumes into account</td>
</tr>
<tr>
<td>Major erosion linked to climate and topography</td>
</tr>
<tr>
<td>Ecozones (zones forming between two natural environments)</td>
</tr>
<tr>
<td>Characteristics</td>
</tr>
<tr>
<td>Very rich environments (example: mangroves), highly diversified</td>
</tr>
<tr>
<td>Obvious regression in these environments over the past few decades</td>
</tr>
<tr>
<td>Impacts</td>
</tr>
<tr>
<td>Consumption of natural a transition space and risk of plant or animal species disappearing</td>
</tr>
<tr>
<td>Disappearance of buffer effect these environments</td>
</tr>
</tbody>
</table>
What potential does the natural environment have in this area? Are there any significant trees, plants or natural habitats which should be preserved, or which may be sensitive to the effects of road development? How extensive are the changes expected in the road layout and road use? Is the road improvement likely to induce increased human activity in areas with significant flora and fauna?

**Sensitivity**
The sensitivity of an environment can be evaluated using such criteria as:
- Wealth of species within the population
- Originality of the population
- Presence of migration paths of large animals
- Evidence of soil conservation problems
- Importance of the water cycle to local flora and fauna.

For mountainous regions, an important role of vegetation is holding soil in place, while in an alluvial plain the major factor would be vegetation's function in protecting the water table. Roads, almost without exception, have a strong effect on the migration patterns of animals, and hence on mating and other animal activities which involve moving from place to place.

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**Figure 10.2 The mangrove ecosystem**

Mangrove ecosystem

- Continental forests
- Non-saline environments
- Interface between continental and oceanic ecosystems: brackish water salinity 3-25
- Oceanic environments salinity 33

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**Figure 10.3 Example of ecological succession**

Phase 1: grass
Phase 2: bush
Phase 3: copse
Phase 4: composite forest
Species assessment
Given the variety of plant and animal species present in an ecosystem, it is almost impossible to evaluate the number of species present without extensive data gathering. The small species are particularly difficult to itemize. In this case, a practical solution is to use biological indicators—standardized methods for quickly and effectively measuring the species present in an environment, and for evaluating the ecosystem.

Ecological assessment
The natural environment is a valuable heritage for the populations of the earth. It is difficult to assign a value to environmental heritage, but ecology attempts to do so. Each ecological system has its own characteristics that can be estimated and consequently evaluated against other ecosystems. Ecology looks at the following criteria when assessing ecosystems:

- Intrinsic characteristics of plant or animal populations relative to their composition and their wealth or to their structure. Biodiversity is measured in terms of number of species and density for a given species; originality within a given geographic area; and quantity of living matter expressed in biomass. It should reflect the interactions between the components of an ecosystem, its organization in space, and its nutritional networks.

- The role the flora and fauna population plays in the ecological universe; for example, the transitional effects between neighboring populations, the flow of matter and energy bio-geo-chemical cycles, animal migrations, and dissemination of seeds. The surface area covered by the plant or animal population and its degree of isolation are also vital factors. However, these criteria are not all equally pertinent in assessing the sensitivity of an environment. Their choice depends on the context and type of project.

As it is sometimes difficult to gather all the data on the natural environment within a fairly short period of time, the assessment should make use of the various documents available, including geographic maps, pedological (soil) maps, vegetation maps, climate maps, scientific and technical studies, research reports, and any aerial or satellite photographs (box 10.1). This information may be available from research centers, specialized institutions, government departments, and other project offices.

Mitigation measures
Avoidance
Where possible, road developments would be located away from sensitive environments to avoid severe impacts on flora and fauna.

BOX 10.1
Monitoring long-term changes in the road environment

In Ethiopia, aerial photographs and satellite images were used to monitor and analyze changes in the environment of a highway between 1980 and 1993. The road under study crossed an area previously untouched by modern development and virtually isolated from the outside world. It was anticipated that population and land use changes would begin immediately after construction of the new road, while traffic flows would increase only gradually.

In the study period, the population of the study area increased from 92,000 to 211,000, in part for reasons not related to the road. The number and size of smaller villages increased, and major villages doubled in number. Past aerial photographs and more recent Landsat and Spot data (see chapter 21) were used to establish four situation maps, and the data were stored in a geographic information system.

A comparison of the land use maps over this period shows the growth of human settlements and land under moderate and intensive cultivation. A large bamboo forest has been cleared, and the remaining forest is threatened. While the area has a high potential for agricultural development, there is a need to take measures to prevent erosion, loss of soil fertility, and further reduction in forest areas.

Bibliography


Community life and economic activities

KEY POINTS

- Roads are provided to bring benefits to community life and economic activities, for example through improved access, lower transport costs, and better markets for local products and services.

- Road improvements can, however, have wider effects on community life and business, considerably beyond the direct impacts of road construction and improved access. These impacts sometimes substantially disadvantage affected individuals and communities, and failure to address them early in project development may cause later disputes and delays.

- Bigger roads and increased traffic can reduce accessibility of local activities adjacent to and across from the right of way, disrupting the traditional patterns of everyday life and business. These cutoff (or “severance”) effects are difficult to quantify and are a frequent cause of community concern with road improvement or construction in populated areas.

- Local activities may encroach onto road space, and their removal for road widening or traffic efficiency improvements may disturb the economic and social amenity of the community. It may be possible to incorporate measures in the road project to balance and compensate for these changes.

- New or improved roads may bypass communities, reducing traffic and business activities on existing routes. The overall impacts on the bypassed area are sometimes positive, but concerns need to be identified and addressed.

- Consultation with affected individuals, local community representatives, and other interested parties is often required to identify problems and appropriate actions.

KEY WORDS: Access, severance, bypass, encroachment, social analysis, consultation, participation, traffic, transport mode, land use
The objective of road improvements is generally to bring benefits to surrounding communities, through lower transport costs, and better access to markets, jobs, goods, and services such as health and education. In the case of some major highways and freeways, benefits may accrue mainly to long-distance travellers and goods, and local benefits may be minimal. In either case, road construction and rehabilitation projects can lead to modifications in the community or social environment around the road, influencing various aspects of lifestyles, travel patterns, and social and economic activities. Recognizing and managing these impacts is an important aspect of the environmental assessment of roads.

**Impacts**

*Severance* of communities occurs when roads or other infrastructure cut traditional lines of travel or communication. This occurs particularly on new and wider roads, especially where traffic speeds are faster and access control or median barriers are used. The alternative routes for local movements are sometimes substantially longer, directly affecting businesses, pedestrians, and users of nonmotorized transport, and often having greatest effects on the poor. It should be noted that existing busy roads may also be hard to cross, and some types of road development (such as pedestrian refuges and traffic signals) could improve access for local communities. Examples are shown in figures 11.1 and 11.2.

*Encroachment* of local community activities onto roadsides, footpaths, bus stops, and even the pavement itself can take many forms, including:
- Markets, kiosks, and selling of goods
- Small business such as cafes and vehicle repair shops
- Uncontrolled stops by buses, taxis, and informal public transport
- Unregulated parking, often associated with business activities
- Growing crops and drying farm produce within or near the road reserve.

Such activities are often found in built-up areas and near busy intersections, where traffic congestion is already heaviest. As traffic flows increase, conflicts increase between these local activities and the efficiency and safety of traffic functions of the road. Further conflicts arise when road improvement plans call for widening the road and reducing encroachments and accesses. Road planners

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**Figure 11.1** Modifications of travel routes due to road construction

- **Fields**
- **Abandoned due to the project**

*Route between the various fields of a farm*

*Before*

*After*
need to recognize that some of these activities may play an important part in community life and business, and changes may be resisted by those who see them as a loss of community amenity for the benefit of through travelers.

Bypass roads can overcome some problems of conflict between road use and community welfare, but they may create other problems. On the positive side, bypass roads reduce the immediate impacts of traffic on the community, and local commercial activities sometimes flourish as a result. On the negative side, communities may fear a loss of business from the diversion of traffic, and some community activities tend to “migrate” to the new route, potentially changing existing land-use patterns and possibly undermining the objective of greater access control on the new route. Environmental assessments for bypass routes need to compare the impacts of the new route with the impacts of not providing it, that is, the effects of growing traffic on existing roads through built-up areas.

Road projects can also cause changes in vehicle flow on the secondary network, possibly creating nuisances if traffic should increase at some locations.

Traditional modes of transport may be disrupted by changes accompanying a road project. Measures which impede road crossings, control bus stopping points, and restrict parking of informal public transport vehicles near busy markets and intersections may reduce the attractiveness of these modes. The barrier or severance effect of roads can increase travel time and distances for short local trips, especially impacting access by walking, bicycle, and other nonmotorized transport. These potential changes need to be assessed alongside the benefits of improved access and transport services provided by a road.

Agricultural activities can be affected when farmland is divided by a new road or increased traffic, possibly disrupting existing farming patterns and connections between fields.

Tourism can be affected both positively and negatively by road improvements. For example, while improved access may benefit the local tourist industry, increased activity may damage tourist attractions if not properly managed.

“Culture shock” can occur when relatively isolated communities are exposed to increased communication with the outside world. This is especially relevant to indigenous peoples, as discussed in chapter 13.

“Gentrification” is a term sometimes used for situations where infrastructure improvements or other factors increase the value of land in a particular area, pushing lower-income tenants and residents out. This is a distributional issue, where, overall, development projects can harm some segments of the community.

Figure 11.2 Changes in travel patterns due to road improvements or increased use
Land acquisition and resettlement are discussed in the following chapter, along with the related issue of property values. The effects of construction, rehabilitation, and maintenance works are discussed in other sections of this handbook.

All of these factors give rise to justifiable concerns on the part of local communities about the effect of road proposals on their lifestyles and welfare. It is always preferable to identify and discuss these concerns early in the road planning process, so that the magnitude of likely effects can be more fully understood and designs can be modified most effectively.

Impact identification and assessment

Many of the impacts discussed in this section are difficult to quantify by purely objective means. The first requirement is to identify possible impacts, in order to determine the need for and scope of further investigations. This preliminary assessment can be achieved from an examination of:

- The project activities: Do they involve new or modified alignments, road widening or roadside works, substantially increased traffic flows or faster speeds, new traffic patterns, or other changes which could impact the surrounding social and economic environment? Will they generate substantial construction traffic or temporary traffic arrangements affecting nearby communities?
- Roadside activities: Are there significant social and economic activities within the road reserve? What are the main local travel patterns, including walking, cycling, and informal public transport, which may be affected by road changes?

For simple rehabilitation and maintenance projects on roads with little roadside activity, the preliminary assessment may determine that impacts of this type may be minimal, and no further assessment would be required. Where there is a possibility of wider impacts, a more extensive analysis is required, usually including consultation with affected people and other interest groups. Consultation processes are discussed in some detail in chapter 4. This section briefly discusses important elements for the assessment of impacts on community life.

Preliminary social analysis

Social analysis is used to identify the individuals and groups who should be involved in consultations, typically including:

- Beneficiaries of the project
- Potential losers, or those at risk of negative impacts
- Other stakeholders or parties with an interest in the project, such as governments and elected officials, experts, and nongovernment organizations
- Others whose local knowledge may assist in identifying potential impacts and assessing the viability of alternatives.

The social analysis should examine relationships between these groups and individuals, identifying the forms of consultation which are most likely to elicit the knowledge and input of people with different interests. It is particularly important to identify those with greatest power to influence decisions and outcomes related to the project assessment process.

Procedures for consultation meetings need to be established from the social analysis. What types of information need to be elicited, and how will decisions be taken? This information can help to focus meetings on issues.
most relevant to the environmental analysis of a project.

Potential pitfalls of community consultation should also be carefully considered as part of the social analysis. Poorly planned consultations can be dominated by vocal or powerful minorities, they can generate tensions within communities or between interest groups, and they sometimes create uncertainties about project objectives, scope, impacts, or options.

**Consultation**

Chapter 4 on information, consultation and participation discusses a number of methods, such as public meetings, expert seminars, interview surveys, neighborhood displays or discussions, on-site consultation, and rapid appraisal techniques. It is often found desirable to use several different consultation activities to successfully consult with the full range of people with an interest in a project. Consultation, in any of these forms, should include the following elements:

- **Establish the rules of the game.** What is being requested, and how will it be used?
- **Provide information.** This might cover the project objectives, the problems it aims to address, the alternatives considered. Supporting data may be provided on current traffic and travel patterns and economic, social, and environmental issues.
- **Elicit input.** This may begin with concerns of those consulted and better information on travel, social, and environmental issues which may affect project impacts. Once the options and issues are clear, input may be requested on priorities and potential solutions to identified problems.
- **Discuss implementation.** Local knowledge can be very helpful in ensuring that proposed measures can work and are likely to be sustained.

This process may take place on more than one occasion in the development of a project. For larger projects, it is common for initial meetings to provide and elicit information, while later meetings discuss solutions and their implementation, perhaps after more analysis and investigation.

**Social surveys**

More extensive interdisciplinary studies may be required for major projects, to establish baseline data and forecast the likely effects of alternative actions. Depending on the issues identified in preliminary analysis and scoping, further study may be required on:

- **Social factors:** Customs, value systems, social classes, hierarchical relationships, and kinship structures; organizations, leadership structures, and decisionmaking; social activities and facilities, such as health, education, and sources of energy.
- **Anthropological factors:** The various ethnic groups concerned by the project, and their living habits; populations vulnerable to any confrontation with other cultures.
- **Economic activities**, their reliance on transport, and potential for growth.
- **Transport factors:** Existing roads and communications; travel patterns including those by foot and nonmotorized transport; data on traffic and its daily or seasonal variations.

There are numerous tools for defining impacts on community life and economic activity, including local data banks, statistics, censuses, and surveys of the population. Maps can be particularly useful for identifying key activities, vulnerable locations, and constraints.

**Rapid appraisal techniques** offer a range of methods for obtaining social data with limited resources and in a shorter time scale than...
those usually required for more extensive surveys. These are discussed further in chapter 4, and in the references listed in the bibliography of this section.

**Mitigation measures**

**Avoidance**

Impact on human activities can be avoided if a road project follows a route far from any human settlement, or if changes made on existing roads are minimal.

**Mitigation**

*Severance* of local access routes can be limited by taking account of local movements at the road design stage and by making provision for improved crossings or alternative access routes, or both, through the use of signals, intersections, pedestrian refuges, underpasses, overpasses, service roads, and alternative arrangements for local traffic circulation. The quality of alternative access can affect property values and the extent of financial compensation, as discussed below.

Effects of *bypassing* local businesses can sometimes be mitigated by providing service areas adjacent to the new routes and by encouraging local communities to make use of the new opportunities provided. In other cases, roads can be designed to encourage long-distance travellers to continue to utilize local businesses.

Enforcement of *encroachment* regulations are often the responsibility of local authorities whose primary concern is not traffic flow and safety. Road agencies need to work with other levels of government to make sure that the interests of both the community and road users are well served.

Where road improvements require removal of some local activities from the road reserve, a common mitigation measure is to provide alternative space for these activities nearby. The covering of drains or the purchase of additional roadside land, for example, can permit continued operation of roadside stalls, customer parking, or pick-up areas for informal public transport services. An example is shown in figure 11.3.

*Residential and business areas* should be identified early in project planning and considered as constraints in the choice of alternative routes, the planning of temporary traffic diversions, and the location of worksite camps.

**Compensation**

Resettlement and compensation may need to be considered for those whose housing, land, welfare or livelihood is directly affected by a project. This is discussed further in the following chapter on land acquisition and resettlement.

Compensation may also be provided through the restructuring of property layout and access arrangements disturbed by road construction.

More global compensation for loss of community amenity can often be provided through small landscaping and roadside improvement measures which take advantage of the changes in road layout and operation to provide alternative spaces and facilities. Service roads, roadside markets, and bus parks are examples of facilities sometimes included in road projects to provide for commercial or social activities which are important to community life.

**Environmental study checklist**

- **Baseline data and potential environmental impacts:** Basic information on the nature of the project and roadside activity will identify whether potential impacts are significant. Where further examination is required, quantitative data may cover land use, demographics, economic activities, traffic counts, and travel patterns. These may be supplemented with sociological data on community cultures, organization, and social activities. Many details of the current situation can only be obtained through community consultation, including surveys, questionnaires, and meetings. The impact assessment may include maps of constraints and sensitivities and forecasts of changes in baseline conditions with and without the project.
- **Analysis of alternatives:** Information on each alternative should include social as well
as economic and environmental impacts, including possible secondary effects on lifestyles, travel patterns, and land use. Where community impacts are significant, the final choice of alternatives may depend not only on technical criteria, but on the priorities and perceptions of those affected.

- **Mitigation plan:** Many options are available to mitigate the effects of road development on the surrounding communities. Technical, financial, and institutional aspects should be considered, to ensure that chosen measures are feasible, effective, and sustainable in the particular social environment.

- **Environmental specifications for contractors:** The main requirement relevant to this section is to ensure that work camps, temporary works, and the lifestyles of construction

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**Figure 11.3 Creation of rest area: Improved facilities for roadside activities**

**Present:** Allowing vehicle to stop on the road is incompatible with the traffic speeds expected of the new road

**Future:** Providing roadside market area and parking—and preserving the traditional "conference tree"—protects local community activities and incomes and improves safety
workers do not have negative impacts on the social and economic welfare of nearby communities.

- Legislation on property rights, expropriation procedures, and compensation requirements, and on public participation and appeal processes, should be considered.

Bibliography


Land acquisition and resettlement

KEY POINTS

- Road projects sometimes require additional land, which must be acquired by the government from current users. While it is sometimes possible to negotiate a price for a voluntary sale of the property, governments often have to use their rights of compulsory acquisition (or expropriation) of properties for public projects.

- The government’s right to expropriate carries with it a responsibility to ensure that those affected do not bear an unfair share of the costs of a project which will bring benefits to others. In the simplest terms, this responsibility should be to ensure that the standard of living of all affected persons is restored to the level enjoyed before the beginning of the road project.

- Three important outcomes of the environmental assessment are:
  - A table of project-affected people categorized by type of impact experienced
  - A schedule of actions or entitlements for each category
  - A plan for implementation, monitoring and remedial actions.

- Official valuations of land and property do not always reflect the full cost to those who required to give up land for public projects, and financial compensation is not always sufficient to enable people to re-establish businesses, markets and social links.

- Some people are more vulnerable than others and have fewer resources and skills with which to reestablish themselves. Examples of more vulnerable populations include the elderly, the poor, the landless, and, in various contexts, small artisans and female-headed households. These segments of the population may require additional assistance if they are not to suffer in the relocation process.

- Even minor widening and rehabilitation can have significant impacts on roadside land uses, which require active consideration in the road planning process.

KEY WORDS: Expropriation, rehabilitation, compensation, access, owner, renter, squatter, business, valuation
Impacts
Use of land for road construction and improvement may entail the voluntary sale or compulsory acquisition (expropriation) of homes, properties, businesses, and other productive resources. By its nature, expropriation causes social disruption and economic loss for the affected individuals and their families. Importantly, the extent of that disruption and loss increases rapidly with the number of people affected.

The impacts of land acquisition are not only economic but also social and psychological. Economic impacts include the loss of a house or business, or the temporary or permanent loss of business income. These can be estimated and costed. Nevertheless, the actual valuation of these losses often proves to be a difficult and protracted process.

The social and psychological costs are more complex, and they are sometimes much more devastating. Neighborhoods can be disrupted and, in the worst instances, broken up completely by large construction projects. People who visit daily and who constantly do small, important favors for each other may be left bereft when they are separated by physical barriers and long distances. Business people may find their clientele cut off from their shops or changing in ways they neither anticipate nor like. These sorts of social and economic changes often find personal expression in physical health problems and various depths of psychological depression.

Impact Identification and Assessment
In preliminary planning for road projects, the approximate number of properties, houses, businesses, and roadside activities likely to be affected by land acquisition should be identified for each option under consideration. In addition, the number of squatters, kiosks, and other informal activities affected by road proposals should be identified and roughly quantified. This provides a first indication of the extent of need for closer investigation of land acquisition and resettlement issues.

Where very minor impacts could occur to existing land users, further study should identify the types of people, land, and activities which could be affected and the availability of simple measures to avoid or mitigate these effects. Can the road design be modified slightly, for example, or is there alternative land available nearby for this activity?

A table of project-affected persons should be developed in all cases where a road project or an alternative under consideration involves taking over land currently owned by others or used for other activities. This table may be somewhat approximate in early stages of project planning, but the details should become precise as options are clearly defined and land surveys and then final design are completed. An example is shown in table 12.1. At each stage, the table should identify the types of people affected (e.g., as owners, renters, employees, squatters); the type of impact on land (e.g., farm size reduced, house or shop acquired, access limited); and the type of impact on people (e.g., reduced livelihood, house lost).

Assessing the magnitude of impacts requires more detailed analysis. For residences, impact identification requires an inventory of houses affected and the extent of property acquisition from each. It also requires a determination of the type of tenancy of each resident and a notion of length of residence. Owners, renters, and squatters are distinct categories of residents under most national laws; only the first—owners—are usually entitled under the law to compensation for expropriated property, even though the latter—renters and squatters—will also have to resettle. The potential for local resistance to change often increases in proportion to length of residence.

Impact identification on businesses requires a slightly different approach. An estimate of temporary financial loss and of temporary relocation costs, if any, will be required for those businesses that will be able to relocate within the immediate area. By contrast, for those businesses that will have to move out of the area or that will suffer a major loss of clientele, it will be necessary for planning purposes to estimate the costs of relocation and reestablishment at a minimum. Allowance should also be made for technical
and financial assistance to modify and adapt businesses to new circumstances. For farmers, economic losses can include the value of crops in the ground and loss of earnings due to unfamiliarity with the new land.

Land acquisition and resettlement actions also have impacts on the remaining residents and businesses, who may be faced with diminished family and community structures and business clientele and reduced property values.

In addition to site inspection and land surveys, household and business interview surveys are often required to establish the magnitude and extent of impacts. Consultation with affected persons and communities can also play an important role in identifying potential impacts and possible alternatives and mitigating measures. This is discussed further in chapters 4 and 11 of this handbook.

In some informal sectors it is not easy to determine exactly who is affected or the nature of likely long-term impacts. Many markets and "squatter businesses" such as roadside kiosks and small workshops are not formally organized, with few if any records of ownership, rental, income, or length of occupancy.

<table>
<thead>
<tr>
<th>TABLE 12.1</th>
<th>Example of categories of project-affected people and proposed actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effect</strong></td>
<td><strong>Action</strong></td>
</tr>
<tr>
<td>1. Lose house, and all land</td>
<td>Resettle proprietor: restore home and lands in new area</td>
</tr>
<tr>
<td>2. Lose house, and some land (land left not viable)</td>
<td>Resettle proprietor: restore home and all lands in new area</td>
</tr>
<tr>
<td>3. Lose house, and some land (land left is viable)</td>
<td>Reconstruct house on remaining land; compensate for land lost</td>
</tr>
<tr>
<td>4. Lose house, and no land lost</td>
<td>Reconstruct house on remaining land</td>
</tr>
<tr>
<td>5. Lose house; landless</td>
<td>Reconstruct house on new plot in original or new area, as proprietors wish</td>
</tr>
<tr>
<td>6. Lose house; renter</td>
<td>Assist with housing in old or new area, depending upon renters’ wishes</td>
</tr>
<tr>
<td>7. Lose house; squatter</td>
<td>Assist with housing in old or new area, depending upon squatters’ wishes</td>
</tr>
<tr>
<td>8. Lose all land but not house</td>
<td>Restore lands within a reasonable distance of home; otherwise resettle proprietor: restore home and lands in new area</td>
</tr>
<tr>
<td>9. Lose some land (land left not viable), but not house</td>
<td>Restore lands within a reasonable distance of home, if possible</td>
</tr>
<tr>
<td>10. Lose some land (land left is viable), but not house</td>
<td>Compensate for lost lands</td>
</tr>
<tr>
<td>11. Lose home-based business income (temporary), but not home</td>
<td>Compensate for lost income</td>
</tr>
<tr>
<td>12. Lose home-based business or home</td>
<td>Reconstruct home in original or new area, as proprietors wish; compensate for lost income during relocation process</td>
</tr>
<tr>
<td>13. Lose neither land nor house</td>
<td>No action</td>
</tr>
<tr>
<td>14. Lose business site; renter or squatter</td>
<td>Provide alternative location with equal or better access, services and business potential</td>
</tr>
</tbody>
</table>
pany. Tax collectors or unofficial market administrators often have detailed knowledge, which can be supplemented by other forms of local consultation. A related problem is that the benefits of compensation and mitigation measures may not go to those most affected and in need, especially if alternative facilities are of a better quality than those lost, and are thus attractive to other more influential groups in the community.

In some cases, property ownership or development rights are not clearly defined under the law. These should be identified as early as possible, as they can take many years to resolve. Examples can include long-term squatters who have established homes and rental arrangements, and property development rights “allocated” to individuals or companies without clear legal documentation.

Mitigation measures

Avoidance
Impacts on roadside land users can be avoided by choosing route locations away from built-up areas and by restricting the extent of road works to avoid interference with existing activities. In some cases the adoption of a reduced design speed, reduced right-of-way land requirements, or design changes such as underground drainage, can avoid impacts on some properties and activities.

It should be noted that the impacts of not acquiring land can also be significant. Many road improvement projects, for example, follow existing alignments and seek to minimize the extent (and cost) of land expropriation. In rural areas, this approach can mean widening roads through villages, towns, and provincial centers. The existing roads are sometimes so narrow that road widening eliminates sidewalks and pedestrian access, with negative effects on informal modes of transport and the quality of community life as discussed in chapter 11. As a second example, adoption of a narrow road reserve can substantially limit options for controlling water flows and soil erosion, with potential negative effects on the natural environment.

Mitigation
As with avoidance, mitigation of land acquisition impacts is primarily achieved by modifying the route or design of a road to minimize its effects on nearby properties and land uses. The design of alternative access to affected properties and the management of temporary works and traffic diversion can also reduce the magnitude of impacts on property and welfare.

Consultation with affected people and other interested parties (box 12.1) can mitigate the impacts of land acquisition and resettlement actions by providing clear and timely information, by fully discussing options, preferences, and likely outcomes, and by designing implementation arrangements taking full account of the needs of those affected. Consultation techniques are discussed in chapter 4.

Compensation
Many countries have laws and regulations governing property rights, compensation,
and appeal procedures for land expropriation. Road planning should allow for the considerable time and money which are often involved in these processes.

Rehabilitation is a term often used by environmental and social specialists to describe the process of reestablishing lifestyles and livelihood following resettlement, recognizing that this involves more than just replacing lost property or assets. The term is confusing when applied to road projects, since it is also used by engineers and planners to describe construction works to bring a deteriorated road back to its original condition. "Social rehabilitation" may require additional financial, technical, and coordination assistance, which is rarely provided for in legislation or administrative arrangements.

Legal compensation procedures generally provide only for the owners of property and make no allowances for renters, employees, and squatters. Additional arrangements need to be defined to ensure that these affected groups are not substantially disadvantaged by land use changes and that they are assisted in relocating and reestablishing their homes and incomes. In general, assistance provided under an environmental action plan will supplement legal compensation for land owners, but will be the major means of compensation and mitigation of losses experienced by other persons affected by the project.

Monetary compensation poses a number of concerns in resettlement and rehabilitation programs.

- Valuation of assets: book (or tax) value of properties is often used, but is usually significantly lower than present market value. Even present market value can leave people less well off than before. If, for example, there are many resettled people seeking scarce land, prices may rise, so that resettlers may have to pay more than the previous market rate just to replace their former assets.
- Property markets do not always exist in a form which allows ready replacement of land and livelihoods. It may be difficult, especially in densely populated areas, to buy property with similar agricultural, housing, or community environment to that expropriated for road development.
- Timing of payments can be critical. When properties are valued but payment delayed for several years, the ultimate monetary compensation may not reflect market rates at the time of payment. This consideration is especially important when high inflation characterizes the national economy, so that delayed payments result in depreciated compensation.
- The manner in which compensation is paid can be important to the long-term welfare of the recipients. People not used to money—or with insufficient resources for current expenses—will typically spend the compensation payment on other articles of consumption, thus becoming vulnerable to landlessness or homelessness. In many instances, it is therefore useful to pay most of the compensation into a blocked bank account, from which the funds are released when the resettler has identified and contracted for a new home, business, or land. A small amount—up to 20 percent of the funds—can be paid in cash to the resettler so that he or she can take care of extraordinary domestic needs.

In many cases it is preferable to restore or replace any asset taken, rather than provide financial compensation. Productive economic assets represent the owners' livelihoods, and they must be replaced in the new site before the relocation occurs.

Environmental study checklist

The specifications for resettlement in roads projects are guided by the basic notion that the conditions of life, including income, must be restored to at least those levels that existed before the project was undertaken.

Baseline data and potential environmental impacts

It is important to identify project-affected persons and properties at the earliest stages of road planning, and to make more detailed assessments as the project is more fully defined. Impacts should be categorized in terms of the types of land, persons, and activities affected, and whether the effects are temporary or permanent. Where initial analyses identify possi-
ble effects on land use, land surveys and interview surveys are generally required to provide detailed information.

**Analysis of alternatives**
Valuation of impacts should recognize the full costs experienced by those faced with relocation of homes and businesses, and they should take account of renters, squatters, and employees as well as property owners. Consultation is essential in the comparison of options, since their impacts will depend on the priorities and perceptions of those affected.

**Mitigation and compensation plans**
These should take account of:
- **Entitlement**: National legislation, which determines the categories of ownership, often recognizes only formal, registered title. However, in many countries there are various forms of informal or unregistered title, including usufruct (permanent or temporary use) rights, seasonal use rights, rights of access to commons, and others. *It is imperative to catalog and compensate all of the various forms of rights, whether legally recognized or not.* If this is not done, people with only informal rights may not be formally compensated for assets and rights that are actually lost, which means they may be impoverished.
- **Expropriation and valuation procedures** should be investigated, to determine: whether properties are actually surveyed and assessed or simply estimated from national valuation tables (which may or may not be current); whether book or market values are used; whether negotiation and arbitration procedures are in place and work on a timely basis; and when and in what manner payments are made to the affected parties.
- **Relocation assistance** arrangements should be reviewed, to determine: what assistance will people be provided in the search for new locations; what follow-up support will be provided; and what can be done for those who, for whatever reason, fail to reestablish their homes or businesses.

- **Follow-up procedures** are required to monitor the effectiveness of compensation, relocation, and assistance programs, and to provide additional assistance to those who have not been sufficiently protected by the initial arrangements. Responsibilities, entitlements, and finance for these remedial processes need to be clearly defined in the action plan, taking account of the overlapping responsibilities of different government agencies.
- **Institutional capability** to carry out the relocation and rehabilitation operation must be assessed. Road construction agencies rarely have the in-house capacity to manage resettlement operations. Thus, they look either to other government agencies or to private sector agencies. The concerns here are to clearly define responsibilities and to establish whether the agency or organization selected has the charter to deal with all the affected parties (e.g., small shops and enterprises), the legal right to acquire and transfer land title, and the administrative capacity to carry out the operation required.

**Environmental specifications for contractors**
These should ensure that temporary works and traffic management do not unduly impact nearby land users and that remedial measures for resettled persons are implemented in ways which take account of their social and economic concerns.

**Legislation**
Legislation on the following issues should be considered:
- **Property rights, expropriation procedures and compensation requirements**
- **Public participation and appeal processes**.
Bibliography
Indigenous or traditional populations

KEY POINTS

- Indigenous or traditional populations require special attention in road projects because they possess a unique cultural heritage and have limited ability to assert or defend their interests and rights in land and other productive resources.

- Indigenous peoples are sometimes defined in national legislation, or are identified by a distinct language and culture, a close attachment to (isolated) ancestral territory, and often a subsistence-oriented lifestyle. There is no clear definition that fits all countries and regions; the important issue is to identify groups that are particularly vulnerable to new developments and increased outside contact.

- Environmental assessments and actions should protect the interests of these populations to ensure that their dignity, human rights, and cultural uniqueness are respected and that they do not suffer adverse effects because a road is put through or near their traditional territory.

- Consultation processes and economic, social, and environmental measures must therefore be *culturally compatible* with the needs of the indigenous communities.

KEY WORDS: Culture, tradition, subsistence, isolation, contact, health, access
Impacts

Roads in areas settled by indigenous or traditional peoples typically open up the area to development and settlement by other peoples, upsetting the fragile ecological balance between people and the land and, no less importantly, displacing and diminishing the indigenous population.

For many traditional peoples, the land is a sacred, inextricable part of themselves, their lifestyles, and their livelihood. Indeed, the flora and fauna are typically considered beings, who are integral parts of the cosmos. Thus the very definition of self is bound up with the land, and its flora and fauna, in a manner wholly alien to outside economists, planners, developers, and settlers.

Roads can too easily disrupt this balance. New and improved roads bring increased contact with outside peoples, who either occupy the land for farming or exploit other resources such as minerals, forests, or wildlife. The increased competition for existing resources can put the indigenous populations at a disadvantage, especially when settlers introduce ecologically inappropriate, and unsustainable, production systems.

Often, indigenous populations have no recognized land ownership and are not compensated for the land that is taken. Rather than fight for their rights in an alien national legal system, they may withdraw from the new population centers, thus increasing the population pressures on other, already traditionally occupied lands. In extreme instances, physical conflict can break out between settlers and the indigenous populations, as the latter try to reclaim their heritage.

Further, the new arrivals, as well as the road construction crews, often bring serious health and social problems, including disease, alcohol, and unemployment, which destabilize traditional lifestyles and can take a heavy toll among relatively isolated indigenous populations.

In short, the physical and cultural stresses placed by roads on traditional peoples can lead to major disruptions to their culture, lifestyles, and welfare. While these pressures are not due to the road alone, road planning therefore must take careful account of the delicate situation of many traditional peoples in isolated areas.

Impact Identification and assessment

Assessing the potential impact of roads on traditional populations requires an extraordinary sensitivity to the culture and the ways of these populations.

An estimate of the population living in the affected area is the first step in impact identification. It is then necessary to understand the social organization of these peoples, including the size of community groups and the basis for their composition and the extent of their traditional territory. It is also critical to assess their productive systems over the course of the year, such as hunting methods, food gathering patterns, and fishing and farming techniques.

Spokespersons are identified for consultation, including indigenous community leaders and, if necessary, intermediary individuals or organizations, who can act as the most effective representatives for their interests. Traditional populations have very weak access to national and regional political structures, and their human rights and traditional land rights may not be legally recognized. Consultation may identify the capacity of indigenous groups to coexist with increased development, and the likely effectiveness of various mitigating options, such as provision of alternative lands and restriction of access by outsiders.

Disturbances to the existing ecological balance are potential impacts which must be seriously considered. Traditional peoples usually exploit the land and its resources in a sophisticated and sustainable manner. The loss of resources and intrusion of settlers can substantially disturb that delicate balance. What may happen to the flora and fauna in an area, which is an integral part of the indigenous peoples' traditions and sense of self, is important both for the viability of traditional cultures and the natural environment of the region.
Mitigation measures

Avoidance
Road location is the major long-term preventative measure available to road planners. Major arteries should be routed around or between indigenous areas if at all possible. If this is not technically or economically feasible, every effort must be made to ensure that the prospective road does not encroach upon the productive resources and the sacred sites and burial grounds of the indigenous populations.

Control of access may also be considered, for example, by an indigenous reserve with restricted entry.

Mitigation
Where impacts are unavoidable, road agencies should act to protect and preserve the traditional rights of these populations in the formal legal arena of the country.

The major means for mitigating any deleterious impacts of a road is consultation and participation. Indigenous populations are very diverse; some may welcome new roads, others may oppose them. Consultation can help road planners understand and incorporate local views and opinions; for example, so that the road follows the most mutually acceptable and least destructive route, and mitigation measures are realistic and culturally compatible with the needs of the indigenous communities.

Local consultation also provides an opportunity to determine whether traditional groups wish to remain in the area or to relocate to some other area. In the former case, some restriction of access may be considered, and authorities may wish to employ indigenous populations as scouts and guards in order to ensure that any incoming population does not overexploit the area. In the latter case, the authorities can assist the group in moving. In both instances, consideration should be given to helping indigenous populations to obtain formal legal title to their territory.

The manner in which indigenous populations are consulted will vary in the particular case. Sometimes, representatives of the agency can contact the population directly. Other times, it may be preferable to go through intermediaries who are familiar with and known to the affected population, such as nongovernment organizations or individuals who have worked in the area for an extended period of time. Whoever conducts these consultations, the discussions should be held in the indigenous language, illustrative materials should be provided to facilitate clear and complete comprehension, and sufficient time must be allotted to ensure full and thorough discussion among the population.

When a road goes through an indigenous area that is also a protected area (indigenous reserve, national park, ecological reserve, protected forest), the local population can be employed in the design and implementation of the management plans. Indeed, depending upon the wishes of the local population, locals can be employed on the construction crews.

Road design can assist in the restriction of access to sensitive areas. Construction of a road with narrow shoulders, large drainage ditches and no stopping places can substantially discourage through traffic from stopping along the route or from entering and exploiting nearby areas.

Compensation
Monetary compensation will likely mean little to traditional peoples, and it may not be adequate to protect their culture and livelihood. Replacement of lost land and resources is an important and viable option, but it is generally difficult in practice to match the quantity and quality of what is lost.

Compensation can also be provided through provision of alternative facilities (e.g., dams) and resources (e.g., fishing rights, or assistance with small fish-farming activities), and royalties from mining and other development activities. Increased medical and education services can also be provided. In all cases, great care is required in the design of assistance schemes which are compatible with, and do not undermine, traditional cultures and lifestyles. Thorough consultation and social analysis can assist in the design, im-
plementation and monitoring of such measures.

**Environmental study checklist**

- **Baseline data and potential environmental impacts**: Basic information on the presence of traditional peoples and nature of the project and roadside activity will identify whether potential impacts are significant. Where there is any evidence of such effects, extensive further examination is required because of the dramatic impacts which can result. Experts and knowledgeable locals can provide basic information on community structure, numbers, lifestyles, and resource use. Consultation should then be very carefully organized, taking account of leadership structures in the affected communities and possible differences of view within communities, and utilizing knowledgeable and trusted intermediaries where these are available. This should allow time for thorough discussion and consideration of a broad range of road options and mitigating measures to find culturally compatible solutions. Summary information may include maps of constraints and sensitivities and forecasts of changes in baseline conditions with and without various project alternatives.

- **Analysis of alternatives**: Priorities and concerns of the affected communities should be considered along with the developmental objectives of the road project. Implementation issues will be important in selecting options and mitigation measures which can be sustained in the long term.

- **Mitigation plan**: Clear responsibilities need to be assigned for implementation of mitigation and compensation measures, with provision for sustainable financing and remedial actions where the original measures are found to be not entirely successful.

- **Environmental specifications for contractors**: The main requirement relevant to this section is to ensure that work camps, temporary works, and the lifestyles of construction workers do not have negative impacts on the social and economic welfare of nearby communities. Project workers, for example, should be restrained from hunting, fishing, or otherwise using the local resources that are held in common by the indigenous populations.

- **Legislation**: Many countries include specific definitions, clauses, and legal frameworks within their national constitutions, statutes, and relevant legislation. These legal definitions, available from the Ministry of Internal Affairs or its equivalent, determine the status of the indigenous population, the nature of their tenure, and the manner and means of dealing with these populations. Land tenure law is a specific consideration. National legislation will determine whether and, if so, how indigenous populations are to be compensated for the loss of some of their ancestral area. In some instances, indigenous populations are considered the equivalent of legal minors and are thus ineligible to hold land or passports. When the formal legal system so disadvantages indigenous populations, project authorities will have to take exceptional measures to ensure the cultural integrity of those populations and to defend them from encroachment by new settlers.

**Bibliography**


Cultural heritage

KEY POINTS

- Road construction and associated works, such as quarrying and backfilling, can destroy cultural heritage sites or alter their scientific or aesthetic character.

- For large-scale projects, a cultural property survey is normally required, particularly in areas with known previous human occupation.

- Road projects can provide opportunities for the discovery, inventory, or development of previously unknown sites.

- Access to cultural heritage sites is often improved by the road infrastructure. However, adequate measures need to be taken to assure their proper protection, including preparation of a site management plan.

- Road works can include investment in measures to protect significant sites, through improved conservation, presentation, interpretation, facilities, and control to access.

- Failure to plan adequately for heritage sites can lead to significant delays in road projects.

KEY WORDS: Salvage archeology, site transfer, excavation, protection, site regulations, tourism
The term *cultural heritage*, also termed *cultural property*, refers to sites, structures, and remains of archaeological, historical, religious, cultural, or aesthetic value. Cultural heritage, often only partially known and studied, is a record of past achievements and discoveries and a unique expression of human values. Its identification and examination by specialists are helpful in understanding the significance of a site, according to its aesthetic, historic, scientific, and social value. The construction of a road may endanger this heritage, but it may also lead to the discovery of new sites.

**Impacts**

Road improvement projects can have varying consequences on cultural heritage, such as:

- **Damage** caused by road construction, related works such as quarries and borrow sites, and unregulated access to cultural heritage sites
- **Aesthetic impacts** on cultural monuments and archaeological sites
- **Positive impacts** of improved access to sites recognized for their cultural value; and updating of the region’s heritage by adding interesting sites previously unknown or overlooked.

**Impact identification and assessment**

In some cases, potential historical or archaeological issues can be identified through public consultation or through knowledge of prior archaeological or cultural finds in the region. But in many areas the information base is too limited, and field surveys will be necessary.

If the presence of historical and archaeological sites appears to be likely and relevant for the road route and its surrounding area, the services of an archaeologist or historian may be required. The following sources of information may be investigated:

- **Inventories** of sites classified according to applicable legislation: specialized publications from the departments of the Ministry of Culture, universities, and research centers; descriptions of ruins and sites; excavation reports.
- **Bibliographic** sources, including travellers’ accounts.

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**Figure 14.1 Identification of archaeological sites from aerial photography**

The drawing illustrates one phenomenon that can be used in aerial reconnaissance of archaeological sites. A buried wall (1) can cause lower humidity prejudicial to the growth of cereals (A). An ancient ditch cutting into the subsoil (2), to the contrary, promotes cereals’ growth and makes them greener (B).
Maps: Field boundaries conserving traces of ancient roadways, and other cartographic evidence of cultural heritage.

Toponyms (place names): A habitat rich in traces of ashes from fires or homes destroyed by fire might bear the significant toponym of “black lands.” Taken from texts of old maps and drawings, they provide considerable useful information that may identify settlements which are no longer readily visible.

Aerial photography: Low altitude aerial photography has now proven one of the best ways to investigate and detect archaeological ruins (figure 14.1, box 14.1).

Field surveys for cultural sites generally include the following steps:
- Carry out a rapid field survey, usually on foot, to identify the pattern of site distribution in the area under examination.
- Determine the area covered by the remains and the points that present the highest concentration of artifacts; record their location, characteristics, and state of conservation—carrying out sample soundings, if necessary.
- Authenticate and localize the information gathered. For example, where did the people get the stones they used to build their houses?
- Analyze the remains for their archaeological, historical, scientific, religious, or aesthetic significance. Assess the state of conservation of the remains and recommend needed protection measures.

When a comprehensive inventory of the cultural sites has been prepared, priorities can be determined, taking into consideration site classification according to legislation, extent of the sites depth of archaeological artifacts below the ground surface, and condition and significance of the site. These priorities can be as follows:
- Highly important sites and protected sites, to be preserved intact
- Sites of special cultural interest, to be avoided whenever possible
- Potential sites, requiring surface prospection and limited archaeological sounding and recording.

Box 14.2 gives an example for the city of Ningbo in China.

Mitigation measures

Avoidance
Where possible, road construction should avoid an alignment that cuts through known cultural sites (figure 14.2). If an important site is uncovered during road works, possible realignment of the road should be considered.

In some unusual cases it is preferable to leave a cultural site buried beneath the road. This may involve raising the level of the road, as shown in figure 14.2.

Mitigation
Where cultural heritage may exist near a road project work site, specific contract clauses

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**BOX 14.1**

**Aerial photography for archeological surveys**

The discovery of an archaeological site by aerial photography is rarely an accident, but rather the result of a systematic investigation of clues derived from examination of aerial evidence. The following details should be paid particular attention:

- **Topographic and vegetation clues:** Their study can reveal anomalies in the structure of the landscape (fossilized ruins; terrain anomalies, such as mounds or tells).
- **Phytological clues:** Anomalies in the growth of crops (figure 14.1), reflected in differences in height and color, vary according to the nature of the underlying structures (details of vegetation corresponding to archaeological structures).
- **Pedological clues:** Anomalies in the surface characteristics of soil are reflected in variations in shading. A plow may dig up building materials lying just under the surface, whose color contrasts with that of the surrounding earth.
- **Hygrometric clues:** Anomalies in soil humidity can be revealed by a color that differs from that of the superficial layers (darker color of the soil and that of vegetation).
should be included to define responsibilities of companies and workers who discover new sites or artifacts, or who damage known sites. Dialogue between the road department and the ministry in charge of cultural heritage needs to be frequent and continuous to avoid situations which either damage the cultural site or delay the road project. In some countries, road projects have been delayed for years because of a lack of procedures governing cultural sites, or lack of funding for the

**BOX 14.2**

**Road works in historic urban areas: China**

Under the Zhejiang Multi-Cities Development Project, the World Bank is helping to finance the improvement of urban infrastructure in the city of Ningbo. Due to the rapid growth of the city, the existing road networks are inadequate to carry the present level of traffic. Current growth trends suggest that economic activity and traffic volume will increase in Ningbo. Significantly, the existing roads correspond in large measure to the roads known as early as the 11th century. The original consulting road engineers, when thinking of ways to improve traffic flows, chose to continue the already established traffic routes. This option, however, involved the widening of roads in the historic core of the city and the destruction of numerous historic structures including temples that are the center of activity for religious communities.

In view of the possible negative impacts of the proposed works on the cultural heritage of Ningbo, specialist architectural conservators were called in to carry out an analysis of the cultural heritage assets. They ranked the buildings and sites adjacent to the proposed road alignment according to architectural and cultural significance, and recommended alterations to the road in order to spare as many of the important structures as possible. The value of a small lake in the center of the city for recreational and visual amenity was also emphasized by the consultants, who urged that the city take steps to conserve the unique character of the lake. They also suggested the creation of conservation areas. In their report they raised the question of creating a ring road rather than routing all traffic through the city.

The suggested road alignments have been adopted by the city. An inventory of cultural property in the project area has been undertaken. In view of the tremendous pace of new building in Ningbo—as in other cities in China—it is urgent to establish zoning and development controls that guide the development of roads and infrastructure while protecting historic building ensemble and areas. Planning for these resources at an early stage in project identification is the best way to ensure cost-effective and adequate conservation.

**Figure 14.2 Avoiding or covering archeological sites**
protection, study, or restoration of these sites. In practice, a cooperative relationship between road builders and archeological specialists is essential. If cultural heritage requirements are too rigid, some site discoveries may be hidden or destroyed to avoid compliance. On the other hand if road workers fail to allow for heritage sites, substantial delays and cost increases can occur.

Compensation
Examples of compensation actions may be:
- Tourist development of the site where heritage elements are conserved and showcased.
- Classification of the site as protected under appropriate legislation. For sites of international quality, UNESCO listing as a World Heritage Site may be proposed.

Environmental study checklist
- **Baseline data and potential environmental impacts:** Identification and prioritization of historical and archeological sites prior to route surveying, pinpointing highly sensitive areas, and archeological sounding
- **Analysis of alternatives:** Options for avoidance of sensitive areas
- **Mitigation plan** should include rules for the construction phase and archeological supervision
- **Environmental specifications for contractors** should specify actions required and person responsible and should define the nature of additional development work and its scope
- **Legislation** in effect in the country or region, and regulations regarding various classes of protected sites.

Bibliography


A aesthetics and landscapes

KEY POINTS
- A road can be visually attractive or unsightly, depending on its physical layout within the surrounding landscape and the attention given to detailed design, planting, and maintenance.
- A well-designed road should harmonize with its environment, take advantage of terrain and views, and include some of the best examples of local flora. In some cases it may become a tourist attraction in its own right.
- Even on existing alignments, careful attention to landscaping can alter the appearance of a road and the way it is perceived by road users and the surrounding community.
- Coherence, readability, hierarchy, and harmony are concepts used in landscape design of roads.
- Good landscaping is not necessarily expensive and should take maintenance into account.

KEY WORDS: Aesthetics, integration, landscape structure and pattern, architectural heritage, photomontage, coherence, harmony, stability
Visual attractiveness should be considered in the planning and design of all roads, but especially those passing through areas of special physical beauty. A well-designed road which takes the landscape into account may attract visitors. A poorly designed road project (poor alignment, heavy structures, unattractive concrete slope protection, or excessive cuts) will reduce interest in the site and reduce the beauty of the environment for both travelers and local residents. Many countries have “tourist routes” and “scenic byways” which are traveled partly for the experience of the landscape. While these usually take advantage of striking physical features, their attraction is based on the aesthetic quality of the road, and can be enhanced by good design.

Impacts

When a road is built across a landscape, it modifies the natural and visual equilibrium for the road user and the residents. Negative impacts are expressed by a lack of harmony with:

- **Natural relief and morphology of the landscape.** This can occur if the route: doesn’t follow the relief as closely as possible and causes the formation of major cut and fill zones, out of character with the terrain in height, length, and incline of slopes; cuts transversely or diagonally across a system of parallel valleys; or doesn’t avoid landscape with an uneven relief.

- **Hydrology:** If road construction results in rerouting and channeling of a waterway.

- **Vegetation:** If the road project results in deforestation; destroys or doesn’t bypass isolated trees, avenue trees, or hedges; or interrupts vegetation continuity in a valley or other setting.

- **Structure and pattern of the landscape:** If the road cuts obliquely through a rectangular farm system, creating numerous isolated plots which, apart from being unattractive, may be difficult to cultivate.

- **Urban or village areas:** If the road separates two urban centers or doesn’t take a strong existing urban pattern into consideration. Roads can also modify the way a city or village evolves and expands and can encourage new urban expansion; this may be an objective of road development or an unexpected outcome with undesired visual and community impacts.

- **Architectural or cultural heritage:** If the road crosses through a park of historical interest or blocks or cuts off the view of archaeological or cultural interest. Related issues were discussed in the previous chapter on cultural heritage.

**Impact Identification and assessment**

A landscape analysis can help to define features of the landscape, using available cartographic and photographic documents and tours of the site. In order to facilitate comprehension by the public, the tools used are mainly visual and include:

- One or more thematic maps, depending on the dimension of the site and its complexity (relief maps, maps of urbanization, vegetation, landscape, main features, synthesis).

- Schematic cross-sections to explain the structure of the landscape and the distribution of its various components in relation to the relief.

- Photographs, usually arranged by landscape unit or theme to support the analysis.

The road alignment or the various alternatives under consideration can then be integrated into this initial landscape using the following illustrations:

- Maps with route alternatives superimposed over the initial environmental state.

- Photomontages that use photographs taken on-site, or oblique aerial photographs, to simulate the road’s route and impact.

- Analysis of the vertical alignment and cross-sections where the contour of the natural terrain coincides with that of the road’s route. In this way it is possible to visualize the importance of cut and fill zones.

A landscape is a subjective concept that cannot be precisely quantified, and it includes an excessively large number of parameters. A study of the relief, vegetation, buildings, hydrography (watercourses), and land division...
system makes it possible to identify several different landscape units on the site, each unit being defined as a part of the territory with its own special characteristics (relief, forms of land use, vegetation, buildings, color, etc.) and which can be perceived by the eye and enjoyed by the senses. Landscape units are homogeneous parts of the landscape which can be characterized by such criteria such as coherence, readability, hierarchy, harmony, and stability.

- **Coherence**: A landscape is coherent if its various components (relief, vegetation, buildings) harmonize—if they are aesthetically balanced. Contemporary structures, on the other hand, rarely depend on their natural setting. Their coherence is created by forms, colors, proportions, etc.
- **Readability**: A landscape is readable if it is easy for the observer to comprehend.
- **Hierarchy**: A landscape with hierarchy is one with a predominant main component.
- **Harmony**: Harmony means that there is a geometric relationship between the various components making up the landscape. It aims for maximum overall coherence compatible with the widest possible diversity (figure 15.1).

- **Stability**: A stable landscape is one which, although changing, conserves the same characteristics and qualities.

Landscape analysis must keep in mind the overall route, integrating sections studied separately, to avoid creating a project which appears splintered and not cohesive.

**Mitigation measures**

**Avoidance**

It is not possible for a road to avoid influencing its landscape environment. Even maintenance and rehabilitation works can change the appearance of a road, for example through the use of vegetation and shaping of the roadside.

**Mitigation**

**Alignment** characteristics can be selected to best fit the route into the landscape:

- Vertical and horizontal alignment should follow the natural relief as closely as possible within technical constraints such as slopes and radius of curvature.
- Slopes on either side of the road can be varied to match the site's "natural" topography.

**Figure 15.1 Using vegetation to improve harmony between a road and terrain**

Minimum earthwork fits road into site topography

[Diagram of a road with vegetation}

Landscaped earthwork softens terrain using vegetation

[Diagram of a road with vegetation]
Figure 15.2 Computer landscape illustration

Figure 15.3 Taking the view into consideration

Landscape plantation

Eliminating a side of alignment of the avenue to open the view
- Bridges, viaducts and tunnels can be used across steep terrain rather than high cuts and embankments, to preserve the landscape’s visual, physical continuity. Computer landscape illustration may help the road agency visualize the completed road project within the landscape (figure 15.2).
- Views from the road can be revealed, composed, or reinforced by road layout and design (figure 15.3).

* Landscaping and vegetation* proposed for the route should:

- Fit in with local vegetation (trees, shrubs, avenue trees, hedges)
- Replant vegetation to harmonize with or improve existing landscape (figure 15.4).
- Be representative of the road’s category and function
- Respect views and not be planted systematically just to fill in space
- Frame and underscore the various landscape units crossed
- Suit and underscore the various engineering structures
- Ensure user safety by using the landscape to signal changes in the route; for example, using dissymetry of trees in a curve or decreasing the space between avenue trees before entering a curve or village

* Pay attention to the aesthetics of engineering structures by selecting materials that adopt local colors and textures and which give the structure a simple shape.

* Maintenance of roadside vegetation, slopes, and structures can greatly affect visual appearance and can be enhanced by involving maintenance workers in the planning and management of the roadside environment.

* Littering and other eyesores* can be reduced to some extent by:
- Avoiding using too many different types of noise barriers
- Creating regulations or fines for littering
- Regulating advertising along roads and especially at the entrance to cities or towns, such as billboard advertising and storefronts, to prevent unsightly proliferation and protect road user safety.

* User services* made available to motorists along the roadway can help ensure the success of a road project and help avoid concerns such as littering or vehicles making unsched-

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**Figure 15.4 Different types of plantations**

- Avenue trees
- Brushwood
- Avenue trees and shrubs
- Vegetal signal of landscape change ahead
uled stops along the roadway. They also contribute to road safety by allowing drivers to rest or check vehicles and loads during a trip. Examples include provision of rest areas, scenic overlooks, and shoulder pull-off areas.

Compensation
Negative impacts on the landscape can be compensated for to some extent by reforestation of areas to replace those taken up by the construction of the road and rehabilitation of landscape problem areas or “black points.”

Environmental study checklist
• Baseline data and potential environmental impacts: The reference documents are maps of varying kinds, drawings, photographs, and texts. Critical features and locations can be identified using thematic maps of topography, vegetation, buildings, major geographic areas, and the main structural components of the site.
• Analysis of alternatives: Photographs with legends and drawings are used to visualize and explain the landscape characteristics, in order to identify the best route and points on the landscape which require special environmental sensitivity.
• Mitigation plan: This will include aesthetics aspects, especially in relation to road project structures, and other environmental devices such as noise barriers. Implementation and maintenance plans for seeding and planting should cover areas to be planted, species, and techniques to be used.
• Environmental specifications for contractors: In addition to modifying certain elements (screens, bridges), the contractor will have to plant vegetation according to the specifications set by the landscape architects.

Bibliography
Noise

KEY POINTS

- Noise mainly affects urban areas and villages near roads with heavy traffic.
- Noise is one of the most obvious impacts of daily road use. However, noise may also have added impact during the construction stage.
- The use of standardized methods and computer models for assessing noise levels is helpful. It should be noted that measurement methods and standards vary considerably between countries.
- Costs of measures for protecting the environment from noise vary, but they may be combined with landscaping measures to reduce costs.

KEY WORDS: Vehicle, pavement, noise barrier, open-graded pavement, regulations
Impacts
The discomfort caused by noise is a difficult factor to assess; it includes auditory fatigue and temporary lessening of hearing ability. Even when it is not perceived consciously, the discomfort may have harmful consequences on health.

Perception of noise is often relative to the background noise level, so that new roads in quiet areas or noisy trucks at night are often perceived as worse than higher levels of noise in a busy area during the work day.

On the other hand, measured noise levels and potential health impacts are highest where traffic noise combines with other sources, possibly producing an unacceptable overall noise level. Sources of traffic noise include:

- Vehicle noise from the engine, transmission, exhaust, and suspension, which is highest during acceleration, on upgrades, during engine braking, on rough roads, and in interrupted traffic conditions. Poor vehicle maintenance is a contributing factor to this type of noise.
- Rolling noise from the contact between tires and pavement. This depends on tire and pavement type and condition. This is generally greatest at high speed and during quick braking.
- Driver behavior, and particularly use of horns, which contributes significantly to traffic noise levels.

Impact identification and assessment
Road traffic noise problems are greatest on busy roads in densely populated areas. In many areas, noise is one of the most obvious impacts of daily road use. However, in less developed countries its effects are often viewed with lower priority than economic, health, or other environmental impacts.

**Measurement units:** The indicator used to measure sound levels is a logarithmic function of acoustic pressure, expressed in decibels (dB). The audible range of acoustic pressures are expressed in dBA. The human ear perceives a constant increase in sound level whenever the acoustic pressure is multiplied by a constant quantity. The scale of sound levels shows that calm environments correspond to a level of 30 to 50 dBA and that beyond 70 dBA sound becomes very disruptive (figure 16.1). Note that, because the decibel is a logarithmic function of acoustic pressure, the noise levels of two or more sounds are not added up as in conventional mathematics.

Since noise is variable in the course of time, measurements and forecasts are expressed as mean values or other indicators over a given lapse of time.

- The equivalent acoustic level (Leq) is the sound level of a stable noise which contains the same energy as the variable noise over the

**Figure 16.1 Scale of sound levels**

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same period. It represents the mean of the acoustic energy perceived during the period of observation. The equivalent acoustic level of noise during the period 8 a.m. to 8 p.m. is written as Leq (8a.m.-8p.m.) or Leq (12hr).

- L1O(12hr) is an alternative measure, indicating the noise level exceeded 10 percent of the time over a twelve-hour period. For the 18-hour period 6 a.m. to 12:00 midnight, L10(18hr) is typically 3dB(A) higher than Leq for the same period.

Nocturnal noise is generally lower. For example the nocturnal Leq (12a.m.-6a.m.) is typically 10 dB below the Leq (8a.m.-8p.m.), except in the case of especially high nocturnal traffic with a high percentage of heavy goods vehicles.

A building’s exposure to noise is characterized by the equivalent acoustic level in front of (i.e., outside) the facade facing the traffic. This is the most representative indicator of the discomfort caused to the building occupants.

Noise measurement specifications thus require definition of the period of measurement, the noise parameter to be recorded, and the position of the recording instrument relative to the road and adjacent properties.

Measuring instruments: Existing noise levels can be measured using devices called sonometers. While these measurements are valuable base data, they have some limitations in the duration of the sample obtained and the inability to distinguish between sources of noise.

Forecasting methods include equations, computer models, and physical models. The simplest are equations which estimate noise from information on traffic flow, composition, and speed. Computer models are perhaps more widely used and can predict the effectiveness of the protective measures proposed. These are discussed further in chapter 23 on computer programs and models. Factors considered in noise models include:

- Traffic flow, speed, and composition (figure 16.2), and traffic flow variations (platooning, acceleration, and braking patterns)

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**Figure 16.2a** When traffic on a road is doubled, the noise level increases 3 dB(A), all other factors being equal.

**Figure 16.2b** Doubling the speed results in an increase of 6 dB(A)

**Figure 16.2c** Acoustic equivalence between heavy vehicles and light vehicles

**Figure 16.2d** Doubling the distance between the road and the receiver results in a decrease of 3 dB(A) in the noise level.
• Distance between the road and the noise measurement (e.g., a house front; figure 16.3), and relative height and intervening terrain (e.g., cut, embankment, level)
• Gradient of the road (ramp effect), width of the road reserve, and type of pavement
• Effects of the soil or ground surface covering (absorbent or reflecting)
• Quality of vehicle fleet maintenance
• Atmospheric conditions (temperature, wind, etc.).

**Mitigation measures**

**Avoidance**
Noise problems can be avoided by moving the road alignment or diverting traffic away from built-up areas.

**Mitigation**
Motor vehicle noise can be reduced at source (e.g., through vehicle construction, selection of tires and exhaust systems, and vehicle maintenance) or through road design. While vehicle noise emissions can be controlled by vehicle design rules and in-use noise regulations and enforcement, this handbook considers only road-related measures. These include:
• Pavement design and maintenance: open-graded asphalt and avoidance of surface dressings to reduce tire noise in sensitive areas
• Avoiding steep grades at critical locations to reduce noise from acceleration, braking, and gear changes
• Building a road in cut to decrease noise at nearby buildings (figures 16.3 and 16.4)
• Barriers and mounds of various materials, which place a solid obstacle between the road and homes nearby (figure 16.5)
• Facade insulation such as double window glazing, which is usually adopted as a last resort option to dampen noise in buildings. Some of these are compared in table 16.1.

Noise barriers are among the most common measures used. These usually take the form of earth mounds or solid walls of wood, metal, or concrete. These walls are variously known as sound barriers, fences, or screens, and are sometimes used in conjunction with noise mounds to give additional effective height. Noise barriers are most effective if they break the line of sight between noise source and the properties being protected,

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**Figure 16.3 Position between road section and receiver**

![Figure 16.3](image)

Audible nuisance is higher when the residence is located at pavement level

**Figure 16.4 Adaptation of horizontal and vertical alignments**

![Figure 16.4](image)

Move horizontal alignment away and lower vertical alignments
and if they are thick enough to absorb or reflect the noise received. Various materials and barrier facade patterns have been extensively tested to provide maximum reflection, absorption, or dispersion of noise without being visually ugly. Noise mounds require considerable roadside land. For narrow alignments, bridges, and roads on embankments, noise barriers are the only viable option.

Plantations of trees and shrubs have very little noise reduction effect, but they do have a psychological benefit in reducing the perceived nuisance of traffic noise and are often used to “soften” the visual appearance of mounds and barriers.

All these techniques can be combined, if necessary (figure 16.6). A high-rise building, for example, may require a barrier or screen to reduce traffic noise at lower levels, along with facade insulation for the upper floors.

Legislation and regulatory measures can assist noise reduction efforts, for example by:
- Not allowing new residential buildings near major roads
- Requiring by-pass routes for the noisiest vehicles, such as heavy trucks, especially at night
- Limiting speed near especially sensitive areas like schools and hospitals.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Effectiveness</th>
<th>Compared cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth barrier</td>
<td>Same as that of other types of barriers (e.g., wood or concrete); needs more space</td>
<td>Very cheap when spare fill material is available on site.</td>
</tr>
<tr>
<td>Concrete, wood, metal or other barrier fences</td>
<td>Good; requires less space</td>
<td>10 to 100 times the cost of an earth barrier, but may save land cost</td>
</tr>
<tr>
<td>Underground road (cut and cover)</td>
<td>An extreme option for very heavy traffic; requires ventilation if over 300m long.</td>
<td>80 to 16,000 times cost of an earth barrier</td>
</tr>
<tr>
<td>Double glazing of windows for facade insulation</td>
<td>Good but only when windows are closed; doesn’t protect outside areas</td>
<td>5 to 60 times cost of an earth barrier</td>
</tr>
</tbody>
</table>

Figure 16.5 Positioning a barrier or screen

Figure 16.6 Combination of techniques
Compensation
Purchase of properties may be preferable to extensive noise protection measures affecting only a few houses. Monetary compensation for noise impacts is currently offered only in a small number of countries.

Environmental study checklist
• Baseline data and potential environmental impacts. Basic information is needed on current properties that may be affected by road noise, and on areas of potential future development, especially for housing. Where sensitive zones or potential problems are identified, measurements should be taken of current noise levels and models should be used to predict future noise levels, including longer-term (e.g., five-year and ten-year) estimates. The analysis should highlight currently quiet locations likely to experience a large change in noise level, as well as locations which could experience problems from construction noise.
• Analysis of alternatives. Options include road alignment, barriers, pavement design, and building modifications. In some dense urban areas, ambient noise levels are already high, and the noise from new road works may be of the same order. In other cases, there may be tradeoffs between noise protection and increased land take, which is undesirable for other environmental and community reasons. Consultation with affected communities and individuals can assist in identifying preferred solutions within budget and other constraints.
• Mitigation plan. Noise protection measures will mostly be incorporated into road design and construction. Ongoing maintenance actions are necessary, for example, to ensure effectiveness of open-graded asphalt road surfacings. Long-term noise monitoring may also be appropriate.
• Environmental specifications for contractors. Specifications for building noise protection devices should clearly indicate materials and methods of construction and should take account of future road maintenance needs. For construction, quarrying, or other activities in noise-sensitive areas, special attention may be required for equipment noise standards, hours of operation, material haulage routes, and other aspects of work-site management.
• Legislation may incorporate one noise level not to be exceeded for all types of zones (such as Leq(12hr) under 70 dB(A)) or, more realistically, different noise levels for different zones, such as industrial, urban, residential, or rural areas. Lower limits are sometimes specified for nocturnal noise. In framing such legislation, it should be recognized that there are some locations (such as busy urban intersections) where it is very difficult to implement noise limiting measures. It is also important when comparing international practice to take account of differences in noise criteria, measurement methods, and applicability to various types of project. If no legislation exists, objectives can still be established for various types of road projects. Indicative standards used in Western Europe might be not to exceed a Leq (8a.m.–6p.m.) of 65 dB(A) for residences in urban areas, and 60 dB(A) for rural areas. More stringent standards can substantially increase noise mitigation costs. It should be noted again that noise standards are only applicable for a defined measurement method which specifies the location of measurement devices and the duration of measurement.
Bibliography

Road safety

KEY POINTS

- Road deaths and injuries are a very tangible impact of roads on the community environment and may be reduced or increased as a result of road projects.

- Measures and design alternatives which may be considered for dealing with other environmental impacts could also affect road safety. It is therefore important that safety analysis be integrated with the environmental assessment process.

- Road design and roadside layout can have a significant effect on accidents. Design audits are effective in identifying and correcting potential problems.

- Traffic management features, including signs, markings, intersection layout and control, and provision for different types of road user, can also affect road safety. Traffic management plans should be included in road improvement planning to ensure that these aspects are adequately addressed.

- Accident “blackspot” programs can allocate funds to small road improvement projects which reduce accidents at specific locations.

- Road accidents are also affected by policies, regulations, and other actions beyond the scope of a specific road project. Seat belt legislation, drunk-driving programs, speed regulation, and vehicle safety standards are typical examples.

KEY WORDS: Fatalities, injuries, property damage, blackspot, roadside hazards, design audit, traffic management
Impacts
Road accidents result in deaths, injuries, and damage to property. They are a major public health problem and a significant cost to the economy in many countries of the world. While accident rates have been falling in many of the more developed countries, they are increasing in many countries where the road system, travel speeds, and the level of motorization are still growing. Pedestrians and nonmotorized road users are especially vulnerable, so that accident impacts are generally higher where these road users mix with motorized traffic, unless special measures are adopted.

There is often an equity issue in road accident impacts, where road improvements give increased mobility to motorized users, but accident impacts fall most heavily on vulnerable users.

Impact identification and assessment
At a national level, accident exposure is often measured by accident rates (fatalities, injuries, and accident numbers) related to number of vehicles registered or vehicle-kilometers traveled. Since the number of fatalities and the number of vehicles are the most readily available statistics, the ratio of deaths per 10,000 vehicles on register is commonly used. However, because of differences in motorization, traffic mix, and accident patterns, this statistic is of only limited value for comparisons between countries. Accident rates per 100,000 population are also used.

At the project level, local information on accident history may identify unsafe locations on existing roads. Information on similar projects could identify potential problems associated with road improvements, such as increased speed through built-up areas or a lack of pedestrian crossing facilities. Examination of the connections between improved and existing roads may highlight possible new hazards at intersections and inconsistencies in road standards which might not be recognized by drivers.

Accident reporting systems are essential for more in-depth understanding of where accidents occur and what are the main contributing factors. Basic information on numbers of deaths and injuries is essential, and location of these events is imperative in identifying accident “blackspots” where physical improvements are most likely to be successful. Further information can identify the types of people affected (such as pedestrians, motorcyclists, car occupants), the type of maneuver (such as head-on or right-angle collision, single vehicle run-off-road), and the type of location (such as intersection, curve, or divided road). This information is usually recorded by police attending accidents, and its quality and central collation depends on coordination, management, and training effort.

Analysis of accident data is essential to ensure that remedial measures are well targeted and effective. This requires specialist skills and knowledge and should be used both to identify critical problems and to test the outcomes of past safety efforts.

Mitigation measures
Site-specific measures
There are many features of a road and its surroundings which influence the risk of a road accident or the severity of accidents when they do occur. Examples include:

- Pavement and shoulder condition
- The presence of roadside poles, trees, ditches, steep slopes, and barriers
- Signs, markings, intersection layout and control
- Roadside access, parking, and bus stop arrangements
- Provisions for pedestrians, cyclists, and nonmotorized road users (box 17.1).

A useful guide to evaluation and improvement of these components is provided in Towards Safer Roads in Developing Countries, which is fully referenced in the bibliography for this section.

Important steps to ensure that these factors are adequately addressed can be categorized as preventive measures, which reduce the likelihood of future accidents, and remedial actions, which attempt to resolve existing problems. They include:
• **Road design standards**, safety equipment specifications, and training to ensure that design detail takes account of safety concerns and that specific safety features such as guard fences are correctly designed and installed. Effects of some design alternatives are compared in table 17.1.

• **Road design audits**, at preliminary and final design stages, by specialists in road safety and traffic operations. Account should be taken of any inconsistencies between improved road sections and adjacent roads and of possible conflicts with pedestrians and crossing traffic.

• **Traffic management plans**, including details of signs, markings, intersection layouts, channelization of flows, access restrictions, footpaths, bus stops, and crossings. These should be incorporated with road designs, while separate traffic plans should be developed by contractors for execution of road works and temporary detours. Some examples are discussed in table 17.2

• **Blackspot programs**, which set aside funds for low-cost improvements targeting known high-accident problem locations. It is important that these programs include: evidence of actual accident history; proven remedial measures; rigorous analysis of expected benefits;

---

**BOX 17.1**

**Example of countermeasures—pedestrian accidents**

**Subtypes**

- Pedestrians walking along the road in direction of or toward traffic
- Pedestrians crossing the road
- Pedestrian standing on or by the road

**Causes**

- Negligent crossing or walking
- Undefined crossing sites
- Narrow road
- Poor visibility
- High speed
- Rushing into the roadway
- Lack of footpaths

**Countermeasures**

- Improvement of pedestrian and cyclist facilities
  - Widening or construction of shoulders
  - Construction of separate footways
  - Painting of edgelines in order to separate shoulders
- Speed-limiting measures
  - Speed limit signs
  - Constructive speed limiting measures
  - Active police enforcement
- Improvement of visibility
  - Parking prohibition
  - Removal of sight limiting obstacles, plants, etc.
  - Construction of pedestrian bay within street parking
  - Lighting (especially of crossing sites)
  - Use of pedestrian reflectors
- Limiting of pedestrian movements by fences or guardrails
- Improvement of crossing sites
  - (Re)paint zebra crossing and provide signs
  - Provide rumble strips on both sides of zebra crossing
  - Erect warning signs for a pedestrian crossing (outside city center)
  - Construct pedestrian refuge with road signs
  - Provide a line of reflective studs on both side of a zebra crossing
  - Construct raised zebra crossing (with warning signs)
  - Construct level-separated crossing
- Regulations, education and training
and follow-up monitoring of accident experience.

Failure to consider road safety in road projects can sometimes result in "improvements" which lead to higher accident rates. For example, higher speeds can contribute to changes in driver perception of road standards and increased conflicts at intersections or pedestrian crossings, as well as more single-vehicle loss of control accidents. On the other hand, safety improvements can also provide other benefits to road users, such as better bus stops, parking, footpaths, and rest areas.

**Integrated or comprehensive road safety programs**

Apart from physical road features, road accidents are also affected by policies, regulations, and other actions beyond the scope of a specific road project. Seat belt legislation, drunk-driving programs, speed regulation,

<table>
<thead>
<tr>
<th>TABLE 17.1</th>
<th>Examples of effects of physical safety countermeasures on accessibility and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countermeasure</td>
<td>Effect on accessibility</td>
</tr>
<tr>
<td>Footpaths and bikeways</td>
<td>Positive</td>
</tr>
<tr>
<td>Motorways</td>
<td>Positive</td>
</tr>
<tr>
<td>Bypasses</td>
<td>Positive</td>
</tr>
<tr>
<td>Arterial routes in urban areas</td>
<td>Positive</td>
</tr>
<tr>
<td>Junction improvements</td>
<td>None</td>
</tr>
<tr>
<td>Roundabouts</td>
<td>Positive</td>
</tr>
<tr>
<td>Split level interchange</td>
<td>Positive</td>
</tr>
<tr>
<td>Improved cross-section</td>
<td>Positive</td>
</tr>
<tr>
<td>Improved geometric design</td>
<td>Positive</td>
</tr>
<tr>
<td>Guardrails</td>
<td>None</td>
</tr>
<tr>
<td>Improved road friction</td>
<td>Positive</td>
</tr>
<tr>
<td>Street lighting</td>
<td>None</td>
</tr>
<tr>
<td>Bus laybys</td>
<td>Positive</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>TABLE 17.2</th>
<th>Examples of how traffic safety management measures affect accessibility and environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Countermeasure</td>
<td>Effect on accessibility</td>
</tr>
<tr>
<td>Traffic calming</td>
<td>Negative/no effect</td>
</tr>
<tr>
<td>Environmental priority for roads through urban areas</td>
<td>Negative</td>
</tr>
<tr>
<td>Pedestrian streets</td>
<td>Negative</td>
</tr>
<tr>
<td>Access control</td>
<td>Depends on measure</td>
</tr>
<tr>
<td>Priority routes</td>
<td>Slightly positive</td>
</tr>
<tr>
<td>Stop and give-way signs at junctions</td>
<td>Depends on traffic distribution</td>
</tr>
<tr>
<td>Traffic signal control of junctions</td>
<td>Positive/negative (depends on traffic)</td>
</tr>
<tr>
<td>Traffic signal control of pedestrian crossings</td>
<td>Negative (vehicles)</td>
</tr>
<tr>
<td>Speed limits</td>
<td>Negative</td>
</tr>
<tr>
<td>Physical speed-reducing measures</td>
<td>Negative</td>
</tr>
<tr>
<td>Road marking</td>
<td>No effect/positive</td>
</tr>
<tr>
<td>Sidewalks</td>
<td>Negative (vehicles)</td>
</tr>
<tr>
<td>Bikeways</td>
<td>Positive (pedestrians/bikers)</td>
</tr>
<tr>
<td>One-way street measures</td>
<td>Positive</td>
</tr>
<tr>
<td>Traffic control of road works</td>
<td>Negative</td>
</tr>
<tr>
<td>Improved railway crossings</td>
<td>Negative</td>
</tr>
</tbody>
</table>

and vehicle safety standards are typical examples. These can not be dealt with at the level of individual projects; they require coordinated actions from a number of government departments, possibly supported by nongovernment organizations. They are included briefly here because only a proportion of road accident reductions can be achieved through road engineering interventions.

A comprehensive approach to road safety generally requires the establishment of a national road safety council or similar body to coordinate the activities of numerous ministries and agencies with responsibility for various aspects of road safety, including:

- National road safety plan
- Road safety studies
- Accident data system
- Physical engineering improvements
- Traffic police enforcement
- Road safety legislation
- Publicity and advertising
- Traffic education of children
- Driver training and testing
- Vehicle testing and inspection
- Post-accident emergency assistance and medical care
- Road safety research and monitoring.

In many cases the national road safety body has a secretariat providing technical support, especially in the areas of policy development, program evaluation, data quality control, and oversight of special programs. Development of these capabilities requires a long-term commitment to institution-building, training, and funding.

Environmental study checklist

- **Baseline data and potential impacts.** Review of accident data sources and analysis to identify trends, hazardous locations, and road user groups at greatest risk. Safety problems are not the same in all countries, and particular attention should be given to particular local accident experience.

- **Analysis of alternatives.** Consider safety consequences of alternatives, the need for modified design standards, and options for accident blackspot remedial measures as an element of road improvement projects.

- **Mitigation plan.** Review design standards and need for training in safety conscious design principles. Review arrangements and contract provisions for road design audits (and design changes where required), and traffic management plans as an element of road improvement designs.

- **Environmental specifications for contractors** should cover correct practices for installation of safety features such as guardrails, culvert end-walls, and road signs, and traffic safety requirements for the operation of work zones and construction traffic.

- **Legislation, policies and national programs.** Laws, regulations, and enforcement practice related to speed, alcohol, and vehicle safety should be reviewed, beginning with those aspects under the direct control of the road agency directly responsible for the road project (e.g., speed zoning, road signs). In the longer term, road safety programs, policies, regulations, and priorities need to be coordinated with other agencies in the framework of comprehensive safety action plans.
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Transport and Road Research Laboratory. 1989. Microcomputer Accident Analysis Package. Crowthorne: Overseas Unit Leaflet, Transport and Road Research Laboratory.


Construction and off-site activities

KEY POINTS

- This section emphasizes environmental impacts and mitigation measures which are closely related to construction works management. Further detail on impact assessment and options can be found in the sections dealing with each specific impact type.

- The construction process is considered in three stages: site establishment and setup, the construction work activities, and restoration of the site after completion of the work. Each of these has particular impacts and mitigation options.

- Location of work facilities and resources is a key environmental issue during site establishment.

- Erosion is a major risk during construction and can be prevented by prompt planting and control of runoff water. Traffic, noise, waste disposal, and work practices are other important factors which need to be managed by road contractors.

- Restoration of work areas, especially quarries, borrow pits, work depots, and material storage sites, is an important aspect of contractor responsibility, which needs to be allowed for after completion of construction works. Provision is often required for follow-up maintenance of restored vegetation.

KEY WORDS: Erosion, noise, traffic, borrow sites, quarries, soil compaction, restoration
Environmental impacts from construction and off-site activities are largely covered under specific impacts headings earlier in this handbook. This section brings together key issues which may be relevant to construction management practices, but readers should refer to related sections for more detailed information.

**Impacts**

The main environmental impacts associated with the construction of a road are presented below, according to work phase:

- **Work site establishment.** Installation of equipment and materials can cause traffic disruptions, noise, dust, and pollution resulting from equipment cleaning and materials storage and handling. The settlement of temporary workers can have significant impacts on economic activities and resources. For major projects, work-site accommodations are often like temporary towns, usually autonomous and difficult to integrate into the surrounding social environment. Traffic disruptions may also be created by temporary detours and road closures. In some agricultural areas, these can create additional problems during harvest seasons.

- **Site preparation** may involve demolition of buildings, clearing brushwood, tree removal, temporary rerouting of utilities, topsoil stripping, and diversion or rechanneling of waterways. This brings risks of erosion of cleared ground or stored topsoil and increased water runoff and siltation of watercourses. The use of herbicides to eliminate vegetation on the right of way is another potential source of pollution.

- **Earthworks** can bring further risks of soil erosion, and disturb groundwater flows. Excavation that cuts into an aquifer, for example, can cause the water table to drop, disturbing the supply of water to wells nearby and modifying vegetation sensitive to soil humidity. The elimination of the upper layers of the terrain protecting the water table increases the ground water's sensitivity to pollution from the surface. Work-site machinery moving around the right of way can create soil compaction, which may harm the soil's potential for future agricultural use and increase the risk of flooding.

- **Quarries and borrow sites** which provide road-building materials can have substantial environmental impacts on soils, water, and the natural environment. Significant environmental problems can remain if these sites are not environmentally rehabilitated.

- **Paving** methods can lead to chemical pollution if materials are not correctly handled.

**Drainage** works often impact water flow patterns and can cause erosion.

Slope protection and roadside planting measures are illustrated in figures 18.1 to 18.3.

---

**Figure 18.1 Environment and maintenance phase**

(A) Erosion occurs due to incorrect shaping of the subgrade and the failure to plan for runoff, plus insufficient upkeep.

(B) Correct shaping of the subgrade, careful compacting, plant coverage, and the installation of channeling help prevent erosion. Taking the environment into consideration avoids subsequent pavement maintenance costs.

**Figure 18.2 Different techniques for slope vegetation renewal**

A basic technique: alternate rows of herbaceous plants

A sophisticated technique: laying of sod over a layer of top soil
Mitigation measures
Impact avoidance, mitigation, and compensation options are discussed for three stages of the construction process: setting up the work site, works execution, and restoring the site after completion of the road work.

Organization of the work site
Many potential impacts may be avoided by taking preventive measures when setting up a work site. Location of borrow sites, stockpiling areas, work depots, and worker accommodation can avoid sensitive areas, taking account of needs for access traffic and waste disposal.

Management of works execution
Measures to prevent erosion are of major importance during the works phase, and can include:

- Planting on cleared areas and slopes as soon as possible, reusing stripped topsoil
- Temporarily covering the soil with mulch or fast-growing vegetation
- Intercepting and slowing water runoff
- Protecting slopes by reshaping, rock fill, and other methods.

Impacts caused by clearing brushwood and trees can be limited by cutting and using the wood and removing stumps. Problems of dust can be avoided by periodically watering or oiling the site. Noise problems (figure 18.4) can be minimized by using silenced equipment, following noise control regulations and limiting work hours near residential areas.

Pollution from chemical products can be limited by following recommended procedures and not using them during high wind. Traffic management plans for both construction vehicles and diverted traffic should minimize impacts across the entire affected area.

Restoration of the site after the work phase
Site restoration requires a well-designed planting program matched to the needs of local vegetation, with follow-up maintenance and remedial measures as required, over several years. Quarries and large borrow sites can be landscaped and developed for a variety of natural, economic, or recreational uses. Work site facilities, such as wells, water storage, sewer systems, and buildings, are sometimes converted to local uses on project completion.

Environmental features of road projects vary considerably, so each must be examined with ingenuity and common sense. Environmental protection measures should be included in the specifications to the contractors and may require a special briefing or training on the site.

Table 18.1 gives an idea of the mitigation measures by theme, and box 18.1 gives some simple examples of contract clauses. These

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**Figure 18.3** Trees on both sides of the road

Advantages: safety, shade, protection of pavements

**Figure 18.4** Noisy earthmoving appliances

Necessary monitoring: installation of irrigation and protection from livestock necessary for successful growth

CONSTRUCTION AND OFF-SITE ACTIVITIES
### TABLE 18.1
**Construction: mitigation measures**

<table>
<thead>
<tr>
<th>Theme</th>
<th>Observations</th>
</tr>
</thead>
</table>
| Soils                     | • Choose the best work period to limit risks of erosion. Avoid rainy season  
                            • Create a specific stockpile for topsoil to be reused as such  
                            • Plan dialogue with local authorities for use of excess soil                                                                        |
| Water                     | • Do not locate site installations or production plants in sensitive places (e.g., near drinking water intakes)  
                            • Provide a used motor oil recovery system  
                            • Avoid water accumulation points (good temporary drainage of site)  
                            • Provide sufficient settling for pollution from particles                                                                             |
| Air, noise                | • During work execution, noise can be limited by using quiet equipment, installing temporary barriers or screens, and by working at specific hours  
                            • Limit dust with a sprinkler system  
                            • Be careful when setting off explosives that can cause damage due to vibration                                                        |
| Natural environment       | • Limit clearing to surfaces absolutely necessary for the road project  
                            • Avoid poaching or damage to natural environment during work execution  
                            • Economize the use of wood                                                                                                             |
| Population, economic activities | • Restore access during work execution  
                                   • Border work site by fencing or other means  
                                   • Plan specific itineraries for site machinery traffic  
                                   • Define traffic rules encouraging contractors to respect highway regulations                                                          |
| Risks                     | • Plan an emergency procedure in case of accidents, the pollution of ground water  
                            • Define safety rules for work site personnel—dangerous materials handling, fires, etc.                                               |

### BOX 18.1
**Examples of simple environmental clauses in contract specifications**

*(See also the detailed examples in chapter 19)*

**Installation of work site**

The contractor shall submit the work site for inspection and shall define the facilities to be created. He shall limit disturbances to the environment for the site selected and for residents in the immediate vicinity, both in surface (clearing of brush or trees, water flow, waste storage) and in depth (rupture or pollution of ground water).

The contractor shall execute, upon work completion, all work necessary to restore the site. The inspector shall write up a report outlining the site reclamation prior to official delivery.

**Preparation and supply of quarry material**

During the work phase, the contractor shall:

- Preserve trees during materials stockpiling
- Level stripped materials to facilitate water percolation and make natural grass planting possible
- Restore the natural flow to its previous state
- Eliminate the damaged areas of the site by distributing and hiding massive blocks of rock
- Create runoff recovery ditches and conserve access ramps, if the quarry is declared fit for use as a watering point for livestock or residents.

The contractor shall, upon work completion and at his own expense, restore the environment around the site. A report will be submitted by the inspector certifying that such site restoration work has been completed.

**Tree planting**

The contractor shall plant trees at locations defined by the inspector, provide the recommended protection (clay brick wall, fencing, etc.), supply the required water and if necessary replace dead trees. He shall provide complete maintenance for a period of one year after planting, including: watering, cleaning out the bed at the foot of the tree, etc.

The number of trees planted, along with the execution of protection and the digging of beds at the foot of the trees, will be noted down by the inspector on the site records.

This record will be used at the official delivery to evaluate the services actually rendered. Once road maintenance work has been completed, the contractor shall indicate on the itinerary map the planting carried out (position, number).
Rehabilitation and maintenance practices

KEY POINTS

- The impacts and mitigation measures for road rehabilitation and maintenance works are in many ways similar to those for new road construction work, but the magnitude of impacts and area affected are generally considerably less. Further detail on impact assessment and options can be found in the sections dealing with each specific impact type.

- Good maintenance is good for the environment. Erosion, flooding, road accidents, traffic noise, and landscape quality are examples of environmental impacts which are frequently reduced by timely maintenance actions.

- If environmental factors are adequately considered during project design, maintenance costs can be reduced considerably.

- The natural environment is affected by the quality of drain clearing, upkeep of vegetation on slopes and water speed reduction devices in drains, removal of waste materials, and careful use of toxic substances.

- Community and social environment impacts depend on traffic management, noise reduction, and the quality of safety and accessibility features like signs, guardrails, and footpaths.

- Many aspects of roadside vegetation, traffic management, and roadside safety require expert monitoring and worker training to ensure effective maintenance attention and correct work practices.

- Positive environmental improvements can be incorporated into road maintenance and rehabilitation projects, ranging from strengthening natural habitats in roadside vegetation to improving road signs.

KEY WORDS: Vegetation, drain clearing, waste removal, traffic management, safety, natural habitats, herbicides
In many countries an increasing share of road budgets is being allocated to rehabilitation and maintenance of existing roads, rather than new road construction.

Routine maintenance refers to activities such as grading, grass cutting, drain clearing, pothole patching, and shoulder repairs, which are performed at least yearly if not more frequently. Periodic maintenance activities are typically scheduled over periods of several years and include resurfacing and bridge repairs. Rehabilitation involves more substantial intervention to strengthen a road, repair structural defects, and restore the road to its initial condition, often after it has deteriorated to an "unmaintainable" standard. Rehabilitation sometimes also includes changes or improvements to previous characteristics, for instance, by widening, making small alignment changes, or providing footpaths.

Other maintenance activities considered under this section include seasonal maintenance, such as snow clearing and flood repairs, emergency maintenance to reinstate roads after major failures, and the regular upkeep of safety features and road signs.

Impacts
As with other road construction activities, road maintenance and rehabilitation works can contribute to soil erosion, disturbance of water flows, chemical pollution, traffic disruption, noise, and other impacts on surrounding communities and natural life (table 19.1). These are discussed in the previous section dealing with construction and off-site activities, and in earlier sections on specific impact types. Three issues are especially relevant to this section:

- Chemical pollution can be caused by herbicides used for weed control, salt used in winter maintenance, and chemicals used in pavement stripping and resurfacing.
- Waste materials from drain clearing, pavement reconstruction, and other activities can disfigure the landscape and find their way into waterways.
- Safety of road workers and other road users is sometimes put at risk by inadequate traffic management and work zone controls.

Grass and other roadside vegetation presents both an advantage (protecting shoulders and ditches from erosion, slowing flow and propagation of pollution, trapping suspended matter) and a disadvantage (safety, propagation of fires, flooding if vegetation too abundant in ditches).

Maintenance work also generates positive impacts, eliminating or reducing environmental problems caused by the deterioration of road surfaces, drains, and roadsides. Erosion, flooding, road accidents, traffic noise, and landscape quality are examples of environmental impacts which are frequently reduced by timely maintenance actions. Examples of good management of runoff water are shown in figures 19.1 to 19.3
Environmental maintenance is also required to protect vulnerable roadside species and ensure the effectiveness of environmental mitigation measures. In some intensively farmed agricultural areas, roadside environments provide important habitats for local plant and animal species, which can be preserved and enriched by appropriate maintenance actions.

Mitigation measures
Perhaps the most important mitigation measure related to this section is to make sure that maintenance is done, so that environmental features built into the road design operate effectively.

Protection of the natural environment can be assisted by regular drain clearing, upkeep of vegetation on slopes and exposed surfaces, maintenance of speed reduction devices in drains, removal of waste materials arising from road works, and careful use of herbicides and other toxic or polluting substances.

Impacts on the community and social en-

<table>
<thead>
<tr>
<th>Table 19.1</th>
<th>Effects of maintenance activities on the natural and social environment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil</td>
</tr>
<tr>
<td><strong>Paved roads</strong></td>
<td></td>
</tr>
<tr>
<td>Surface dressing</td>
<td>moderate</td>
</tr>
<tr>
<td>(wearing course)</td>
<td></td>
</tr>
<tr>
<td>General reshaping</td>
<td>moderate</td>
</tr>
<tr>
<td>of shoulders</td>
<td></td>
</tr>
<tr>
<td>Complete resurfacing</td>
<td>moderate</td>
</tr>
<tr>
<td>of shoulder</td>
<td></td>
</tr>
<tr>
<td><strong>Unpaved roads</strong></td>
<td></td>
</tr>
<tr>
<td>General resurfacing</td>
<td>moderate</td>
</tr>
<tr>
<td>of wearing course</td>
<td></td>
</tr>
<tr>
<td>Reshaping of subgrade</td>
<td>significant</td>
</tr>
<tr>
<td>and reconstruction of wearing course</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance actions common to all roads</strong></td>
<td></td>
</tr>
<tr>
<td>Repair of drainage structures</td>
<td>none</td>
</tr>
<tr>
<td>Construction of drainage structures</td>
<td>moderate</td>
</tr>
<tr>
<td>Construction of concreted ditches</td>
<td>moderate</td>
</tr>
</tbody>
</table>

Figure 19.3 Modification of drainage system

Many cut-off ditches (B) prevent the accumulation of water in one ditch (A) and any subsequent risks of erosion
vironment can be improved through well-designed traffic management plans, the use of quiet equipment and limited work hours, and ongoing attention to the quality and possible improvement of signs, guardrails, footpaths, and other features which contribute to safety and local accessibility.

Environmental "blackpoints" or problem locations (such as erosion caused by poor drainage, or steep slopes with insufficient stability) can be identified during the planning and execution of rehabilitation and maintenance works, and actions can be taken to minimize problems.

**BOX 19.1**

**Example contract clauses for use in road maintenance studies**

**Documents to be submitted by the consultant**

The maintenance works study document shall include the route plans, with the physical, geometric, and geotechnical data and the structures and drainage systems; the following complementary information on the road environment shall be specified in it:

- **Road environment data:** Indication of land areas reserved for villages, classified sites, and wooded areas; existing tree plantations and areas suitable for such plantations; existing quarries and borrow pits (location, depth, surface area, water retention issues; site to be improved?); positions of existing side and diverting ditches; areas suitable for construction of diverging ditches or laying-up basins.

- **Data on the state of the road and its deterioration:** Location of eroded areas along the road: slopes, ditches, and approaches to structures; location of drainage areas which have become silted up; general state of structures, erosion or siltation of watercourses.

**Special clause: Preparation of the content of the priced bill of quantities**

The consultant shall establish the preliminary estimates of quantities and prepare the special conditions by (a) separating the opening and closing of quarries and borrow pits from the haulage and application of the materials; and (b) including the cost of a diverging ditch and, if necessary, a laying-up basin. The text that the consultant must include in the works contract is shown in italics.

**Price no. x Preparation of materials at quarry or pit.** The preparation of gravel materials at the quarry or pit (stripping, bulking, and piling) and the restoration of the pit site to its original state upon completion of the works shall comprise the following operations, remunerated at the price no. x:

- storage of the stripped material where it will not disrupt water drainage
- restoration of the natural site around the pit by spreading out the heaps

**Price no. xx Reshaping/compacting with the addition of materials.** The operations of loading at the pit, transportation (optional, because a transport price per ton per kilometer can also be set) and application (reshaping, moistening, compacting) shall be remunerated at price no. xx, the quantities being measured after compacting. The consultant shall specify the volume of material, its position on the road, the final thickness and the source.

**Price no. xxx Construction of diverging ditches.** The price xxx shall remunerate the construction of diverging ditches designed to drain runoff from the roadway to a point where it will no longer be likely to cause erosion harmful to the road or to the environment. This price will be paid per lineal meter.

The consultant shall define these diverging ditches by specifying their location along the road, technical characteristics, planned length, and minimum lengthwise slope. The consultant shall also propose diverging ditches that will enable flooding of old pits.

**Price no. xxxx Construction of laying-up basins.** The price xxxx shall remunerate the construction of diverging ditches designed to carry runoff from the roadway to an old pit. This price shall be paid per lineal meter. The consultant shall propose construction of the laying-up basins wherever the natural site is suitable, avoiding tree cutting. He shall specify the dimensions, volume, and location of the basin with respect to the road and stipulations recording protection of the environment.
Experts in roadside vegetation, traffic management, and roadside safety should monitor maintenance activities to ensure that work practices meet environmental objectives. Understanding the functions and techniques of roadside planting, signs, and guardrails is important for their proper functioning. Training of road workers in these issues can help considerably in their ability to correctly execute and manage maintenance works.

Table 19.1 presents a brief summary of the impacts of common maintenance and rehabilitation activities on the natural and social environment. These are discussed in considerable detail in annex 19.1 at the end of this chapter. Boxes 19.1 to 19.3 provide useful guidelines on key environmental clauses which can be added to contracts dealing with environmental studies, supervision of maintenance works, and works execution.

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**BOX 19.2**

**Example contract clauses for use in road maintenance supervision contracts**

**Article ... records to be kept by the consultant responsible for supervision**

The consultant responsible for supervision shall keep the following records: site report; route report updated to record work done; and proposals with a view to future studies.

- **Site report.** A monthly report on execution of the works shall be submitted by the consultant and shall summarize information regarding environmental improvements effected by the work performed during the month: steps taken by the contractor to preserve the environment and improvements observed upon closing down the site; trees planted (location, number, method of protection, maintenance, monitoring); data on quarries and borrow pits used (location, area, depth, improvements made); length of diverging ditches (partial and cumulative for all new and old ditches); position and volume of laying-up basins constructed; position of strengthening works carried out on approaches to structures.

- **Updating of route plans.** The supervisor shall update the route plans, on which shall be shown all environmental data reported in the monthly reports, specifically: location of tree plantations; locations of quarries and pits used, with updated characteristics of each; location of diverging ditches; state of structures after sand removal upstream and downstream; location, type, and number of anti-erosion devices in the drainage system.

- **Proposals with a view to future maintenance studies.** Once the work is completed, the supervisor shall propose, for the road sections covered, specific arrangements with a view to study of the subsequent maintenance program. These proposals shall cover: improvement of the contract environmental clauses; the special features of the road environment; the chief urgent tasks to be undertaken to improve the environment; and any comments of supplementary data regarding the state of quarries, pits, and drainage.

**Special clauses**

**Article ... Supervision of utilization of quarries and borrow pits.** The supervisor shall ensure proper utilization, by the contractor, of the quarries and pits designated by the detailed design with the aim of lessening the impact on the environment.

- Preparation of materials in the quarry or pit. The supervisor shall designate trees to be protected and oversee storage of stripped material where it will not hinder water drainage; the supervisor shall oversee restoration to a natural state, including spreading of stored stripped material to facilitate water percolation and natural replant growth.

- Volume of stocks of material stored in each quarry or pit.

**Article ... Supervision of the construction and maintenance of drainage works.** The supervisor shall specify location and technical detail of drainage works and debris placement.

- Construction of diverging ditches
- Construction of laying-up basins
- Cleansing of side ditches, diverging ditches, and summit slope and foot slope ditches.

**Article ... Tree planting.** The supervisor shall instruct the contractor where trees are to be planted and the type of protection to be provided. He shall ensure that the contractor makes provision for the water needed for the trees to grow and promptly replaces any dead trees. The supervisor shall draw up a report stating the number and good condition of the plantings at the time of final acceptance.
BOX 19.3
Example contract clauses for use with road maintenance works contracts

Special clauses

**Article ... Worksite installations.** The contractor shall propose to the supervisor the location of work site installations and detail proposed measures to reduce impacts on the environment of these sites and the people living in the immediate vicinity, as regards both the surface area used (clearing, bush and tree removal, drainage, trash dumping) and underground impacts (disruption or pollution of the water table). On completion of the work, the contractor shall do everything necessary to restore the sites to their original state. The supervisor shall draw up a report confirming the restoration before acceptance of the works.

**Article ... Preparation and supply of gravel materials in pit or quarry.** During works execution, the contractor shall ensure: preservation of trees during piling of materials; spreading of stripped material to facilitate water percolation and allow natural vegetation growth; reestablishment of previous natural drainage flows; improvement of site appearance; digging of ditches to collect runoff; and maintenance of ramps where a pit or quarry is declared usable water source for livestock or people living nearby. Once the works are completed, and at own expense, the contractor shall restore the environment around the work site to its original state. The supervisor shall provide the contractor with a report confirming the restoration before acceptance of the works.

**Article ... Cleaning of side ditches, diverging ditches, and summit slope or foot slope ditches.** Debris shall be dumped upstream of the ditch at a sufficient distance from the roadside and spread with a counterslope with respect to the ditch to prevent ditchwater being polluted with fines entrained by rain.

**Article ... Tree planting.** The contractor shall plant trees in the locations fixed by the supervisor, with protection as specified (mud brick walls, wire netting, etc.) and provision of the necessary water, and he shall also remove any dead trees. The contractor shall take care of all required maintenance for one year from the time of planting, including watering, cleansing the area at the base of the tree, and maintaining protection in good condition. The number of trees planted with the installation of protection and the digging of a basin at the base of the tree shall be entered by the supervisor in the site record. This record will be the basis for payment for work actually done at the time of final acceptance. When the road maintenance is completed, the contractor shall enter the plantings made by him (position, number) on the route plan.

**Article ... Documents to be furnished by the contractor.** Upon completion of works the contractor shall provide the route plan with the work performed marked on it and also showing the environmental improvements made (description, location, numbers).

Priced bill of quantities (details as specified in the “maintenance studies” box)

- Price no. x Preparation of materials in quarry or pit.
- Price no.xxx Reshaping/compacting with application of materials.
- Price no. xxx Digging of diverging ditches.
- Price no. xxxxx Construction of laying-up basins.

Bibliography


## ANNEX 19.1
### Impact of road maintenance tasks on the environment in the Sahel

Env. impact codes (Col. 4)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td>relatively SLIGHT</td>
</tr>
<tr>
<td>(B)</td>
<td>relatively MODERATE</td>
</tr>
<tr>
<td>(C)</td>
<td>relatively MARKED</td>
</tr>
<tr>
<td>(--)</td>
<td>deterioration of present state of environment</td>
</tr>
<tr>
<td>(+)</td>
<td>improvement of present state of environment</td>
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</table>

N.B.: This assessment is made up of a set of examples of the relative impact of road maintenance tasks on the environment. The value of the impacts must be adjusted to the environmental context and execution method of each Sahelian country.

### DEFINITION OF MAINTENANCE TASKS

<table>
<thead>
<tr>
<th>Para. ref.</th>
<th>LOCATION ON SITE</th>
<th>DRAWBACKS (--) OR ADVANTAGES (+)</th>
<th>IMPACT (--) and (+) ON ROAD ENVIRONMENTS IN THE SAHEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>materials piled on road</td>
<td>(-) fines carried into drainage systems by rainwater</td>
<td>(A) water polluted by solids</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-) accident hazard for road users</td>
<td>(B) road user safety jeopardized</td>
</tr>
<tr>
<td>2</td>
<td>wearing course</td>
<td>(+) improved evenness</td>
<td>(+B) road safety improved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+) smoother traffic movement</td>
<td>(+B) traffic lanes widened</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+) user safety preserved</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>wearing course drainage</td>
<td>(+) faster roadway drainage</td>
<td>(+B) improved runoff management</td>
</tr>
<tr>
<td>4</td>
<td>workshops, garage and stores</td>
<td>(-) oil, grease and acid spilled on road</td>
<td>(A) local soil pollution</td>
</tr>
<tr>
<td>5</td>
<td>materials borrowing</td>
<td>(-) excessive deforestation</td>
<td>(B) natural environment harmed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-) area stripped, not covered evenly</td>
<td>(B) regrowth of vegetation made difficult</td>
</tr>
<tr>
<td>6</td>
<td>borrow area surface</td>
<td>(+) less natural space taken up</td>
<td>(+C) less harm to natural environment</td>
</tr>
<tr>
<td>7</td>
<td>borrow area</td>
<td>(+) water held in reserve (on impermeable soils) or flows through to replenish groundwater (permeable soils)</td>
<td>(+C) large quantity of water made available for human or animal use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+) natural vegetation reconstituted</td>
<td>(+B) plant cover preserved</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(+) appearance of site improved</td>
<td>(+C) landscape improved</td>
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<tr>
<td></td>
<td></td>
<td>(+) appearance of site improved</td>
<td>(+C) runoff used better</td>
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<tr>
<td>8</td>
<td>stripped area (spreading of piles) and drainage ditches (to be dug)</td>
<td>(+) appearance of site improved</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>workshops, garage and stores</td>
<td>(-) same as para. 4</td>
<td>(-) same as para. 4</td>
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<td>10</td>
<td>site access lanes for maintenance vehicles and equipment</td>
<td>(-) during the work, increased traffic and greater risk for users of the road</td>
<td>(B) vehicle traffic hindered</td>
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<tr>
<td></td>
<td></td>
<td>(-) pedestrian or animal traffic hindered or made dangerous</td>
<td>(B) pedestrians and animals endangered</td>
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<td></td>
<td></td>
<td>(-) dust</td>
<td>(B) air polluted</td>
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<tr>
<td>11</td>
<td>roadway: materials piled on road</td>
<td>(-) dangerous obstacles for road users</td>
<td>(B) users placed at risk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-) in wet season, fines are washed off into drainage systems</td>
<td>(A) water polluted by solids</td>
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<td>Unpaved Roads: Control of washboard surface</td>
<td>12</td>
<td>verges and ditches</td>
<td>(-) lateral ridges, obstruction of drainage and entrainment of fines by rainwater</td>
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<td></td>
<td>13</td>
<td>roadway</td>
<td>(-) residual ridges on surface</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>road surface</td>
<td>(+) smoother surface</td>
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</table>

| Unpaved Roads: Light reshaping without compacting | 15 | verges and ditches | same as para. 12 | same as para. 12 |
| | 16 | roadway | (-) accentuation or reduction of roadway camber | (-) stones left behind | (-) dust | (-C) traffic hazard | (-B) air pollution |
| | 17 | road surface | (+) smoother surface | (+) enhanced traffic safety | (+) better roadway drainage | (+C) improved traffic conditions | (+B) better water drainage |

| Unpaved Roads: A. Reshaping with sprinkling and compacting without addition of material | 18 | verges and ditches | same as para. 12 | same as para. 12 |
| | 19 | roadway | same as para. 16 | same as para. 16 |
| | 20 | road surface | (+) better shaping of roadway | (+) enhanced traffic safety | (+) better roadway drainage | (+) washboard surface takes longer to develop | (+C) more lasting improvement of traffic conditions | (+C) better water drainage |

| Unpaved Roads: Periodic Maintenance of Unpaved Roads | 24 | verges and ditches | (-) lateral ridges left and pooling of water with risk of erosion of roadway edges and slopes | (-) entrainment of fines by rainwater | (-) side ditches filled up with waste materials | (-B) concentration of runoff water along the ridges and erosion of slopes | (-B) water pollution by solids | (-B) obstruction of ditches and of access for local residents |
| | 25 | roadway | (-) accentuation or reduction of roadway camber | (-) stones left behind | (-) dust generation and risk of traffic accidents | (-C) steep crossfall = traffic hazard | (-A) air pollution | (-B) impairment of road safety |
| | 26 | road surface after works | (+) improvement in road safety | (+) roadway drainage | (+) washboard surface takes longer to develop | (+) possibility of establishing vehicle parking area in the larger villages | (+C) improved road safety | (+C) better water drainage | (+C) improved quality of life |

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<table>
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**REHABILITATION AND MAINTENANCE PRACTICES**
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<td>same as para. 25</td>
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<td>Complementary operation: supply of materials (A.1.2 A1) and loading and hauling (A.1.2 B1)</td>
<td>46</td>
<td>villages</td>
<td>(+) provide for off-road vehicle parking areas in the larger villages</td>
<td>(+C) enhancement of quality of life (+C) improved safety for road users and local people</td>
</tr>
</tbody>
</table>

### Roadsides Elements:

#### Roadside Maintenance: Manual or mechanical clearing and pruning

| | roadway, shoulders and ditches | (i) weeds and branches left lying where cut (shoulders, ditches) | (A) obstacles to traffic (B) water drainage through ditches blocked |
| | villages, crops, vegetation | (i) burning of debris (ii) risk of fire spreading to surroundings (ii) herbicides entrained by water | (C) harm to natural environment and crops, and quality of life affected (C) destruction of local peoples' homes (C) chemical pollution of water |
| | slopes, shoulders, sides of ditches | (+) elimination of burning (+) use of manual tools (+) plants not crushed by grader (+) stumps and rootstocks of bushes, etc., retained | (+C) conservation of plant cover (+C) stabilization of slopes, ditch sides and shoulders (+C) erosion reduced |

#### Roadside Maintenance: Manual or mechanical ditch

| A. Clearing of trash dumped or carried into ditches | area where trash is dumped in ditches | (i) water drainage blocked (ii) reduction of water-carrying section of ditch | (B) overflowing, spreading of runoff (B to -C) draining of fouled water |
| | shoulders and roadway | (i) saturation of roadbed and slopes (ii) submergence of roadway and risk of serious rutting under traffic | (B) instability of slopes, creep of shoulders and roadway (C) risk of users getting stuck in the mud |
| | heaps of material cleared from ditch | (i) piles close to edge of ditch | (C) ditches become clogged quicker |
| | trash cleared from ditch | (+) natural vegetation regrowth possible with anchoring of soil | (+B) limitation of water pollution (+B) improvement of natural environment |

#### Roadside Maintenance: Manual or mechanical ditch

| B. Ditch erosion control | ditches: bottoms and sides eroded | (i) ditch sides destabilized (ii) entrainment of lines | (C) destabilization of soil qualities (C) regressive erosion |
| | shoulders | (i) degradation of shoulders (ii) instability of saturated areas (ii) regression erosion in wet season | (B) water pollution (B to -C) traffic hazard |
| | actions on water drainage areas: diverging ditches, laying-up basins | (+) reduction of ditch slope and slowing of water velocity (+) limitation of ditch length or of drainage area (+) reduction of runoff | (+B) soil conservation (+C) no water pollution (+C) less erosion of road |
| | actions to strengthen eroded ditch sides | (+) destruction of ditch sides reduced (+) strengthening of soil resistance | (+C) reduction of erosion and water pollution (+B) protection of natural environment adjacent to ditches |
| Roadside Maintenance: Maintenance of drainage structures and Control of sand encroachment upon structures | 58 | structure obstructed | (-) water drainage constricted (-) bottlenecks and overflows | (-C) rapid erosion of fine soils (-C) water pollution (-C) major disruption of movements of goods and persons |
| Roadside Maintenance: Control of sand encroachment upon structures (continuation) | 59 | clearing of deposits | same as para. 53 | same as para. 53 |
| Roadside Maintenance: Control of erosion of structures | 60 | foundations eroded | (-) destruction of supports (-) road cut by collapse of structure | (-C) rapid erosion of fine soils (-C) water pollution (-C) major disruption of movements of goods and persons |
| | 61 | erosion of banks | (-) bypassing of abutments (-) destabilization of slopes of banks and embankments (-) road cut | (-C) rapid destabilization of soil of banks (-C) water pollution (-C) halting of movements of goods and persons |
| | 62 | repair of structure foundation and cutoffs | (+) protection of foundation soils | (+C) reduction of erosion and water pollution (+B) improved drainage |
| | 63 | rockfill or cribs on slopes (banks, embankments) | (+) improved stability of bank and embankment slopes (+) strengthened erosion resistance | same as para. 72 |
| Roadside Maintenance: Maintenance of kerbs, gutters and rain pipes | 64 | kerbs, gutters, rain pipes | (+) limitation of erosion of shoulders and slopes | (+B) reduction of water pollution (+C) improved drainage |
| Roadside Maintenance: Stabilization and maintenance of slopes | 65 | high slopes | (-) considerable runoff (-) regressive erosion (-) slides | (-A/B) water pollution by solids (-A) if cohesive, (-C) if sandy modification of soil stability |
| | 66 | summit ditch - limitation of drainage area upstream | (+) less runoff | (+C) less erosion |
| | 67 | steps in slope of bank | (+) runoff broken up (+) drainage split up | (+B) less modification of soil (erosion) (+B) less water pollution by solids |
| | 68 | protection of slopes in erodible soils (topsoil, planting, fascines, facing) | (+) heightened soil resistance | (+C) elimination of local erosion (+C) drainage control |
| Roadside Maintenance: Planting and Tree Maintenance | 69 | reservations outside of shoulders or roadway | (+) improvement of soil fixing | (+B) lessened soil instability (+C) improved landscape |
| | 70 | shade areas | (+) rainwater recovery (+) maintenance of soil moisture | (+B) improvements of quality of life in villages |
| Roadside Maintenance: Maintenance against sand encroachment upon road | 71 | roadway (work done with equipment) | (-) expanding of dune/road contact area (-) yearly increase in volume of encroachment | (-C) hindrance and hazard for users |
| | 72 | maintenance of means used to prevent sand encroachment | (+) better protection of road (+) less sand to be cleared | (+C) improved traffic and road safety conditions |
| Roadside Maintenance: Maintenance of upright signing | 73 | danger, priority and prohibition signs | (+) information on areas with traffic hazards | (+C) preservation of safety of users and of local residents |
Risks associated with road works and traffic operations

KEY POINTS

There are four main types of environmental risk associated with roads:

- The measures undertaken to minimize environmental damage may be unsuccessful
- Accidents may occur in the construction and maintenance of the road, causing exposure to hazardous chemicals or injury to workers
- Accidents may occur in the transportation of hazardous goods on the road
- Natural disasters such as flood, fire, landslides, and earthquakes may involve the road environment, and the road may be a key factor in emergency response planning.

Some of these eventualities have a small probability of occurrence, but potentially serious consequences, and hence need to be considered during the environmental assessment of road projects.

KEY WORDS: Hazardous materials, accidental pollution, occupational health, fires, floods, landslides
Impacts
Failure of environmental mitigation measures could result in impacts like those discussed in earlier sections, such as erosion, lowered water tables, wildlife driven out, community severance, increased road accidents, and disruption of indigenous lifestyles.

Construction of a road involves occupational health and safety risks for road workers in the storage and handling of dangerous materials and in the operation of heavy machinery close to traffic, slopes, power, and watercourses. Examples include:
- Exposure to dust particles or toxic fumes from chemicals used in road works and material testing
- Exposure to lead paint in maintenance of old steel structures
- Potential for collapse of trenches and scaffolding
- Risk of accidents involving road traffic.

Daily operation of a road involves the transport of hazardous materials, which could spill in the event of a road accident. This could pollute ground water, streams, and drinking water and contaminate soil.

Road traffic can also be the conduit for involuntary transport of diseases or parasites, which could affect plants or animals. This is a specialized problem in regions subject to specific plant or animal diseases.

Natural disasters can damage a road and its environment, or a road can be a factor in the propagation or mitigation of the impacts of a disaster. Examples include:
- Fire spreading along a road reserve or unable to cross a wide road
- Floods washing away a road or restrained by road embankments; subsequent road damage or transport restraints arising from water-soaked roads
- Road embankments stabilizing a slope subject to landslides, rockfalls, or avalanches
- Access roads and traffic management plans specifically tailored to disaster response needs.

Mitigation measures
Failure of environmental mitigation measures listed under other sections of this handbook is always a possibility which should be considered and allowed for. The risk of failure can be reduced to some extent by:
- Strengthening staff skills and training in environmental management
- Ensuring management support for environmental policies and action plans
- Monitoring environmental actions and responsibilities and making provision for remedial actions
- Planning for remedial measures where planned actions are not successful.

A typical example is soil erosion, which may still occur even after preventative treatments were included in the road construction program. Failure may have arisen because of lack of contractor training in planting techniques, late planting after topsoil was washed away, poor choice of plants, or lack of watering. In any case, prompt remedial action and

Figure 20.1 Risk of accidents during hazardous goods transport
follow-up maintenance are essential to contain the problem before it becomes worse, possibly destabilizing the road and silting up streams. Road agencies should include provision for this type of follow-up in environmental action plans and should clearly assign responsibility.

Occupational health and safety risks of road works can be limited by clearly defined procedures for the handling of materials, conduct of tests and paving processes, operation of heavy equipment, and construction of trenches. These are sometimes defined in laws and regulations. Specific requirements and training may be needed on:

- Limiting time of exposure to dust particles, chemicals, and noise
- Protective clothing and eyeglasses for specific tasks
- Procedures for handling toxic materials, explosives, and other hazardous substances
- Inspection of trenches, scaffolding, and newly-constructed slopes
- Road safety procedures for road works under traffic.

Contractor responsibilities to workers and the environment may be identified during pre-bid conferences, to ensure that potential bidders are aware of contract requirements and can submit proposals which adequately address the necessary tasks and their costs. This can minimize the likelihood of contractor defaults.

Transport of hazardous materials (figure 20.1) needs to be regulated and monitored, with possible restrictions on route and time of travel to avoid the most populated places and times, and clear marking of vehicles as to the type of material carried. Many road agencies develop policies on hazardous goods movement, with specified routes, requirements on containers and labels, and special permits and police escorts for particularly hazardous materials.

Involuntary transport of diseases or parasites is generally managed by signs and checkpoints in areas affected by specific plant disease problems, to restrict the transport of affected fruits or other plant materials.

Natural disaster mitigation has two aspects of interest to the road manager:

- Road planning and design should take account of possible rare disaster events and should incorporate steps to minimize their impacts. Flood retarding measures, floodways and spillways, firebreaks, fire access roads, and avalanche control measures are examples of road features commonly used to mitigate known problems which affect particular routes.
- Disaster response plans should involve the road agency, to ensure that key roads can be kept open or reopened as quickly as possible and traffic diversion can be implemented as needed. Simple recording of disaster response measures and responsibilities, and regular training and dissemination, are important to success.

Bibliography
Part III
Analysis tools
Satellite remote sensing and aerial photography

KEY POINTS

- Satellite photography is particularly useful for projects covering large land areas. It is recommended for preliminary studies to evaluate the major environmental factors of a road project, and measurement of the dynamics of the environment in time and space, by comparing two images.

- Aerial photographs can be used to assist with mapping out land use for feasibility studies. They provide an alternative source of mapping information when no cartographic documents exist, or when they are inaccurate or out of date. They are also useful in providing up-to-the-minute cartographic evidence.

- Information is prepared by breaking images down into several units, defining a legend for each, and photo-interpreting the images. This is usually followed by on-site verification for a few representative zones.

KEY WORDS: Visualization, 3-dimensional image, recording channels, digital processing, photo-interpretation
Satellite remote sensing and aerial photography have made it possible to improve knowledge in many fields, such as geology, mineralogy, oceanography, hydrology, urban planning, agriculture, and environment. Thanks to these tools, specialists can diagnose the state of forests, pollution of the sea, rate of advance of deserts, condition of harvests, changes in vegetation, transformation of urban spaces—in short, everything that changes on the surface of the globe—and make predictions about future conditions of our environment.

These tools can add considerably to the power and efficiency of environmental analysis for road projects, especially where they involve regions that are geographically heterogeneous or remote. Table 21.1 shows how these tools can be applied for various types of environmental analysis.

**Satellite remote sensing**

Satellite remote sensing provides a number of attractive features for environmental studies:

- **Broad coverage.** Only a few areas of the earth are not fully covered: polar regions that are not flown over and a few equatorial regions where cloud cover prevents recordings for some satellite technologies (figure 21.1).
- **Area covered in one single recording.** Areas of up to several hundred square kilometers can be included, to give a global view to the area under study. This is useful in identifying sensitive areas and route alternatives.
- **Repetition of recordings.** Earth observation satellites provide a regular schedule of recording of the earth’s surface or atmosphere, with recording frequencies in the region of once every few days. This means the information necessary for preliminary studies, as well as for follow-up study of the time-related effects of a project, can be updated as frequently as required.
- **Fineness of resolution.** The precision of satellite images permits their use in some detailed analyses. For example an analysis of structural phenomena such as faults, fractures, and structural movements is useful for evaluating alignments, materials, and soil properties.
- **Wavelength spectra** covered by the recording include visible, infrared, and radar frequencies, which can be utilized in the analysis of vegetation, geology, and hydrography. Photo-interpretation of such data can be used, for example, in locating construction

<table>
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<tr>
<th>Environmental impact</th>
<th>Satellite and aerial photography</th>
<th>Maps</th>
<th>Computer programs and models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil and erosion</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Water</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Air quality</td>
<td>-</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Natural environment</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Community life and economic activities</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Land acquisition and resettlement</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Indigenous or traditional peoples</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Cultural heritage</td>
<td>+++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Aesthetics and landscapes</td>
<td>+</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Noise</td>
<td>-</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Road safety</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

*Note:* +++ Excellent analytical efficiency gains for resources invested. ++ Good cost efficiency. + Limited cost efficiency.
materials near the work site. The materials sought can often be detected from the surface by a change in vegetation or by distinctive changes in the ground surface in desert zones.

At the time of writing, the three satellites most frequently used for environmental images of the earth's surface are Landsat, Spot, and ERS-1.

The satellite image

The shooting technique, known as "multispectral" or "multiband," consists of capturing images of the same geographic zone in several frequency ranges (or spectral bands), also called "windows" or "channels," each defined by an upper and lower frequency or wavelength. Unlike color videotaping, which records three narrow frequency ranges (primary blue, red, and green) corresponding to three types of human retina receivers, satellite receivers are designed to record other channels, which reveal information invisible to the human eye. This specifically involves:

- For Spot and Landsat, three channels covering: red, different from primary red and more sensitive to chlorophyll activity; near-infrared, especially sensitive to the density of plant ground cover; and thermal infrared, especially sensitive to human activity
- For ERS-1, channels in the radar wavelengths.

The data and products of remote sensing are available in digital form (magnetic tape), and as photographic film or prints. Prints usually use panchromatic black and white emulsion, but they can also use infrared-sensitive emulsion for studies of vegetation or water-connected phenomena. Each offers specific advantages. The panchromatic mode (one single wide-spectrum channel) provides finer resolution (10 m instead of 20 m for Spot) than the multispectral mode (several narrower channels), but supplies information on fewer fields. However, digital processing makes it possible to combine two images of the same scene using the two modes, for example using panchromatic for topographic information and multispectral for difference in vegetation or soil humidity.

Accessing satellite photography

The satellite image distribution centers are:

- Spot and ERS-1: Spot Image in Toulouse (France)
- Landsat: EOSAT Company in Lanham, Maryland (U.S.A.).

These companies also have various subsidiaries or correspondents around the world who can be consulted. Some further technical comparisons are provided in table 21.2.

Aerial photographs

Aerial photographs offer the advantage of working at finer scales than satellite images, to visualize relief by stereoscopic study and to update maps of the study zone, which are often out of date. Like maps, aerial photographs typically have a scale that varies from 1:200,000 for coverage of large areas to 1:10,000 for large-scale maps or presentation of localized detail (figure 21.2). Stereoscopic views are created by taking aerial photographs in overlapping strips.

Existing photographs may be obtained from cartography departments of various government and private organizations which make them available for general distribution. In addition, existing photographs may have been prepared specifically for projects dealing with forestry or agriculture. It is often worthwhile to contact the managers of these projects to request any recent photographs.

The supply and use of aerial views is some-

Figure 21.1 Satellite revolution
times subject to some restrictions, for example in the vicinity of confidential areas such as military installations.

Aerial photographs are generally black and white. While there are also color aerial photographs, which make the rapid identification of information easier, at present they are comparatively rare and expensive. These technologies are compared further in table 21.3 and table 21.4.

### TABLE 21.2
**Satellite Recording Media**

<table>
<thead>
<tr>
<th></th>
<th>Landsat</th>
<th>Landsat</th>
<th>Spot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captor</td>
<td>MSS Radiometer (Multispectral Scanner)</td>
<td>TM Radiometer (Thematic Mapper) visible</td>
<td>HRV (Higher resolution)</td>
</tr>
<tr>
<td>Geographic observation unit (scene)</td>
<td>185 x 185 km</td>
<td>185 x 185 km</td>
<td>60 x 60 km</td>
</tr>
<tr>
<td>Repetitiveness of passage same scene</td>
<td>16 days</td>
<td>16 days</td>
<td>26 days (up to over 2.4 days for oblique shot)</td>
</tr>
<tr>
<td>Space resolution</td>
<td>80 x 80 m</td>
<td>30 x 30 m</td>
<td>20 x 20 m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120 x 120 m in thermal</td>
<td>10 x 10 m in panchromatic mode</td>
</tr>
<tr>
<td>Number of recording channels</td>
<td>4 (2 visible and 2 near-infrared)</td>
<td>7 (3 visible, 1 near-infrared, 2 medium infrared, 1 thermal infrared)</td>
<td>4 (2 visible, 1 near-infrared, 1 panchromatic)</td>
</tr>
<tr>
<td>Color and spectral resolution</td>
<td>Blue: 1-(0.45-0.52)μm</td>
<td>1-(0.50-0.59)μm</td>
<td>1-(0.50-0.90) μm</td>
</tr>
<tr>
<td></td>
<td>Green: 4-(0.5-0.6)μm</td>
<td>2-(0.52-0.60)μm</td>
<td>2-(0.61-0.69) μm</td>
</tr>
<tr>
<td></td>
<td>Red: 5-(0.6-0.7)μm</td>
<td>3-(0.63-0.69)μm</td>
<td>3-(0.79-0.89) μm</td>
</tr>
<tr>
<td></td>
<td>Infrared: 6-(0.7-0.8)μm</td>
<td>4-(0.76-0.90)μm</td>
<td>4-(0.50-0.90) μm</td>
</tr>
<tr>
<td></td>
<td>Infrared: 7-(0.1-1.1)μm</td>
<td>5-(1.55-1.75)μm</td>
<td>5-(10.4-12.3) μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6-(2.08-2.35)μm</td>
<td>6-(10.4-12.3) μm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7-(10.4-12.3)μm</td>
<td>7-(10.4-12.3) μm</td>
</tr>
<tr>
<td>Original possibilities</td>
<td>Night recording</td>
<td>Oblique shot and 3D relief</td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 21.3
The role of satellite images and aerial photography in environmental assessments

<table>
<thead>
<tr>
<th>Environmental intervention</th>
<th>Role of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening</td>
<td>Collection of basic cartographic documents: 1:500,000 and 1:100,000 scales</td>
</tr>
<tr>
<td>Scoping</td>
<td>Definition of a map presenting the main factors in environmental studies</td>
</tr>
<tr>
<td>Environmental assessment report</td>
<td>Gathering and studying of aerial surveys, production of synthesis maps for data collected and analyzed</td>
</tr>
<tr>
<td>Environmental monitoring</td>
<td>Cartographic comparison of initial state, expected impacts, actual impact</td>
</tr>
<tr>
<td></td>
<td>Updating of data, confirmation of models, confirmation of impacts</td>
</tr>
</tbody>
</table>

### TABLE 21.4
Comparison between satellite images, aerial views, and cartography

<table>
<thead>
<tr>
<th>Satellite images</th>
<th>Aerial views</th>
<th>Cartographic documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover</td>
<td>(+) Cover of the entire planet, independently of administrative limits</td>
<td>(-) Sectorial cover limited by over-flight authorization</td>
</tr>
<tr>
<td>Digitization</td>
<td>(+) Possibility of digital processing (surface area of crops, dwelling areas and so on)</td>
<td>(-) Qualitative data only</td>
</tr>
<tr>
<td>Level</td>
<td>Tool suitable above all at pref feasibility or feasibility level (scales ranging from 1:500,000 to 1:25,000)</td>
<td>Tool suitable at feasibility level (scales ranging from 1:200,000 to 1:2,000)</td>
</tr>
<tr>
<td>Price</td>
<td>High</td>
<td>Very high for special missions, low views available</td>
</tr>
</tbody>
</table>
Bibliography
Maps

KEY POINTS

- Maps are used both for collecting and presenting environmental information.

- For most locations, a variety of maps already exist and can be located in different agencies and organizations; however, the date should be noted and accuracy should be checked against other sources, usually including field verification.

- Maps can be created, and existing maps can be reinforced, using aerial photographs, satellite images, and data gathered on site.

- Geographic and topographic maps give an overall view of a study area.

- Thematic maps focus on one or more specific environmental parameters, such as geology, soil, or land use.

- Presentation maps illustrate key issues in an environmental study by a synthesis of sensitivities and constraints, in a format which is readily understood by nonexperts.

KEY WORDS: Scale, map matrix, topography, cartography, general map, thematic map, sensitivities and constraints, legend, synthesis, site inspection
Environmental studies require the use and processing of large amounts of data which describe the physical and natural environment as well as human occupancy and social activities. Maps can assist in the collection, analysis, and visualization of this information (box 22.1 and table 22.1), and are particularly used for:

- Obtaining an overview of the characteristics of the study area
- Supplying thematic data relevant to specific environmental fields
- Audio-visual support for information, consultation, and participation activities.

**Maps for a general view**

General topographic maps make it possible to comprehend the overall organization of the terrain, the hydrography, vegetation, roads, and buildings. A general map is already an initial synthesis of the project’s environmental characteristics, and they are often used to provide the initial basic data necessary for environmental analysis. Existing maps can also help in orienting and defining the limits of additional terrain investigations.

Maps of this type can be obtained from local or international organizations concerned with mapping, geography, tourism, or economic development.

**Thematic maps**

Maps which focus on a specific topic or theme are of particular interest during feasibility studies, and the evaluation of a site’s sensitivity to various types of environmental impact. A vegetation map can draw attention to fragile ecosystems such as mangroves or rain forests. A hydro-geology map can reveal the presence of vulnerable groundwater in the vicinity. Figure 22.1 shows the use of map overlays to show environmental constraints, while figure 22.2 shows environmental sensitivities. Typical map scales are given in table 22.2.

Existing thematic maps may be obtained from:

- Government cartographic departments with files of maps on specific topics such as

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**BOX 22.1**

**Examples of useful maps for environmental studies**

- Geologic maps
- Maps of protected areas
- Land use maps
- Hydrogeology maps
- Hydrology maps
- Vegetation maps
- Housing maps
- Pedological (soil) maps
- Agriculture maps
- Pisciculture (fishing) maps
- Road network maps

---

**Figure 22.1 The use of overlays to show environmental constraints**

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*154*
Dense urbanization, very strong sensitivity in respect to right-of-way and nuisance, disturbance of movements.

Sparse urbanization, strong sensitivity in respect of right-of-way and nuisances.

Industrial zone, commercial activities sensitivity to crossings and extensions of itineraries.


Humid natural surroundings interesting as refuge for fauna and flora in constant regression.

Biological interest zone, wealth of fauna and flora. Strong sensitivity in respect of right-of-way, material borrows and all disturbances due to works (especially lowering of water table).

Regional scale zone of biological interest.

Good agricultural land, fruit crops, nurseries, vineyards. Economic wealth, strong sensitivity in respect of right-of-way and disturbance of movements.

Medium grade agriculture land, intensive cultivation (maize), sensitivity in respect of right-of-way and disturbance of movements.

Tree plantings connected with shallow water table. Sensitivity in respect of right-of-way and modifications to water table. Biological interest (complementary to marshes) and forestry interest (popular groves).


Hunting reserves situated in habitats interesting for fauna (marshes, woods, etc.) sensitivity to right-of-way and disturbances (risk of big game crossing the development scheme).

Movement of large fauna (deer, boar) principle passages.

Secondary passages.

Waterways with great piscicural quality (spawning grounds) and high frequentation by fishermen. Access to be preserved.

Waterways of good and fairly good quality. Sensitive to fish breeding.

Catchment of drinking water and protective perimeters.

High value sites and monuments.
public works, transportation, agriculture, armed forces, or population
  - Research departments or universities working in a specific field, such as soils (pedological maps) or agriculture (vegetation maps)
  - Development project offices, which often make use of cartographic data (e.g., climatic maps and road maps) in project planning.

Given their diverse origin, these maps may vary greatly in scale, range, content, detail, and precision. The date of maps is also important in assessing their reliability in representing the current situation.

**Presentation maps**
Maps are used not only for collecting information, but also for dissemination and discussion. Presentation maps may be prepared for different groups of people, such as:
  - Experts and professionals, including various government departments, with an interest in understanding and giving opinions on the project
  - Political representatives at the national, regional, and local levels
  - Affected communities and the general public.

The level of detail and complexity of presentation should be suited to the needs and interests of each group and to the objectives of presentation and discussion at each stage of the project. Impact studies are often illustrated by sensitivity maps, which highlight the environment’s sensivities at the initial state, and constraint maps, which identify impacts on sensitivities caused by the project.

Presentation maps can deal with broad project issues or focus on particular environmental themes or a specific geographic locale. They should be designed to enable most read-

---

**TABLE 22.1**
Examples of the use of maps at various stages of environmental assessment

<table>
<thead>
<tr>
<th>Environmental intervention</th>
<th>Role of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening</td>
<td>Basic maps at 1/500,000 and 1/100,000 scales</td>
</tr>
<tr>
<td>Scoping</td>
<td>Definition of a map presenting the main factors for environmental study</td>
</tr>
<tr>
<td>Environmental assessment report</td>
<td>Detailed thematic maps on specific impacts, and synthesis maps showing key issues</td>
</tr>
<tr>
<td>Environmental monitoring</td>
<td>Cartographic comparison of initial state, expected impacts, actual impact</td>
</tr>
<tr>
<td>Environmental evaluation</td>
<td>Updating of data, confirmation of models, confirmation of impacts</td>
</tr>
</tbody>
</table>

**TABLE 22.2**
Environmental data represented by maps

<table>
<thead>
<tr>
<th>Scales from</th>
<th>Of interest at preliminary study stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:500,000 to 1:100,000</td>
<td>Examples of mapped elements:</td>
</tr>
<tr>
<td></td>
<td>• Main population centers</td>
</tr>
<tr>
<td></td>
<td>• Important roads and infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Main relief features</td>
</tr>
<tr>
<td></td>
<td>• Main hydrology network</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scales from</th>
<th>Of interest at feasibility study stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:100,000 to 1:10,000</td>
<td>Examples of mapped elements:</td>
</tr>
<tr>
<td></td>
<td>• Type of housing (scattered, grouped)</td>
</tr>
<tr>
<td></td>
<td>• Relief symbolized by contour lines</td>
</tr>
<tr>
<td></td>
<td>• Main and secondary hydrographic network with watering places and sources</td>
</tr>
</tbody>
</table>
ers to visualize the project’s effects, using representations which are meaningful to non-specialists.

**Map preparation tasks**
The first requirement is to collect available maps and cartographic documents and to prepare new maps as required, including:
- Topographic or geographic maps, sometimes drawn up from existing photographs
- Thematic maps, possibly drawn up from aerial photographs (hydrology maps) or from on-site surveys or sampling (climatic maps).

Conventional cartographic colors are: blue for all themes connected with water, brown for mountains, green for vegetation, and black for facilities. It is common to adopt a single scale for mapping the characteristics and sensitivities of the study zone. This scale depends on the length and amplitude of the project and on the nature of the map matrix available. A compromise should be reached for the following requirements:
- Drawing up easily readable documents
- Grouping compatible themes
- Drawing up a minimum number of maps, but still retaining the essential information.

The effectiveness of maps can be enhanced by careful attention to the definition of the elements to be indicated and graphics and legends which ensure easy readability.

Synthesis maps which combine key environmental themes are often drawn for the critical phases of the environmental study:
- Analysis of initial state
- Analysis of impacts and comparison of alternatives
- Presentation of accompanying measures.

**Bibliography**


KEY POINTS

- Four main computer applications used in road-related environmental studies are:
  - data banks, for access to existing data and storing and analyzing new data
  - models for impact prediction and mitigation design
  - computer-aided design and drafting software, for production and updating of “layered” maps and drawings
  - geographic information systems, for location-based data analysis and display.

- Some applications require budgeting considerable time and money for training, data entry, technical support, and expert analysis. In most cases, skills and complexity of applications can be progressively developed to match the capacity and resources of the institution or study team.

- Computers offer considerable advantages in the management of data in environmental studies, the display and discussion of data in professional or public forums, the evaluation of options and alternative designs, and the updating of information over time.

- Computer systems can also protect and enhance investments in road and environmental data, increasing its accessibility for users and its long-term upkeep and quality control on the part of data providers.

KEY WORDS: Models, databases, data banks, geographic information systems (GIS), computer-aided design and drafting (CADD), hydrology, noise, pollution
Studying the environmental impact of a road project can require the assimilation and processing of large amounts of information. Computer technology provides a number of useful tools for improving the efficiency, quality, and presentation of these studies. Four types of computer application which are frequently used are:

- **Data banks** and database software for storage, retrieval, and processing of quantitative data and bibliographic reference material
- **Models** for predicting the behavior of various components of the environment and the effectiveness of mitigation options
- **Computer-aided design and drafting (CADD) software**, which can store and display “layers” of environmental data along with engineering design drawings
- **Geographic information systems (GIS)**, which can relate environmental data bank information to a location referencing system and map base, permitting display and analysis of geographic characteristics.

A further application which is less commonly used is **computer-enhanced photography**, which is used to create a visual image of a proposed road or structure for evaluation and consultation on its impacts on the landscape.

**Data banks and database software**
The term **data bank** can refer to several types of computerized information storage and retrieval system used in conjunction with environmental data. The information is stored in computer “files” of at least three types:

- **Text or word processor format**, for convenient printing and updating
- **Spreadsheet format**, allowing some sorting, analysis, and display capabilities
- **Database format**, which provides more powerful query, analysis, and reporting features.

Data banks may contain bibliographic references, environmental data, or miscellaneous supporting information, such as useful addresses, regulations, events, recommendations, and responses. There are two phases in the operation of a data bank:

- **Data entry** Input data can be gathered during the study or taken from existing data banks and may be updated as new information becomes available
- **Utilization**: Using the software to query, sort, select, merge, and analyze data and to prepare reports and displays.

While some data banks are prepared and managed by the team responsible for a project or its environmental assessment, others already exist and may be utilized to search for specific information. These can be found in a variety of government departments, universities, research centers, libraries, and international organizations. Some examples are:

- INFOTERRA, a large international information system on environmental topics (see box 23.1)
- The UN Food and Agricultural Organization’s CARSIS data bank, which covers agricultural topics, including: agronomy, fisheries, aquaculture, food and nutrition, forestry, pedology, water resources, energy, agricultural pollution, agro-development, and education
- The International Road Research Documentation (IRRD) database, and similar bibliographic search systems, which can help in locating reference information on specific topics and regions.

**Computer models**
A model can be used to represent some aspect of the physical, biological, economic, or human environment to allow better study of its behavior. It can be used to forecast future changes in baseline conditions and the likely impacts of a project and various mitigation options. It is not possible to build a comprehensive model of an environment based on all its components; rather, models are used more to analyze how subsystems function. In general, the physical and chemical components are understood better than the biological or human components.

There are a great number of models used in various aspects of road planning and environmental analysis. Three examples are:

- **Hydrology**. Road design usually requires an analysis of rainfall, runoff, the volume and speed of water in drains, and sometimes
stream flows and flood levels. These are used to minimize erosion, flooding, and downstream flow impacts. Environmental hydrology models use similar methods, with additional attention to pollutant patterns. The *Storm water management model* (SWMM) is a typical example, distributed by the U.S. Environmental Protection Agency (US EPA). This model includes three main calculation methods: calculation of flows based on rainfall; calculation of pollutants conveyed by runoff as a function of deposit time (interval between two rainfalls) and incorporating the characteristics of the catchment basin (land use and slopes); and analysis of the impact of buffer volumes on these pollutant flows by simulating the settling and recirculation of the pollutants. The main data to be entered into the model are rainfall, hydraulics (essentially slopes), and land use. The result is a simulation of flow and pollutant concentrations. The impact of these pollutants on the envi-

**BOX 23.1**

**INFOTERRA—environmental database**

Infoterra, a global information system, provides access to a pool of knowledge on environmental issues to governments, industry, researchers, and decisionmakers in 138 countries representing over 99 percent of the world’s population.

The United Nations Conference on the Human Environment, convened in Stockholm in 1972, called for an international mechanism for the exchange of environmental information. The result was Infoterra, established in 1975 and initially called the International Referral System (IRS). From the start it was designed as a decentralized information system operating through a worldwide network of national environmental institutions designated by their governments as national focal points (NFPs) and coordinated by a program activity center (PAC) at UNEP headquarters in Nairobi.

No longer solely a referral system, putting those seeking information in touch with experts who could answer their questions, Infoterra now places increasing emphasis on the direct provision of substantive information. For road project applications, Infoterra could provide general environmental information (for example, information on endangered species, sensitive ecosystems, laws, and regulations).

*How it works*

Infoterra handles more than 18,000 queries a year on every aspect of the human and physical environment, ranging from the control of lead pollution or acid rain to the best means of recycling soft drink containers or the safe disposal of industrial wastes. Over 85 percent of inquiries are responded to with substantive information, sometimes in the form of existing publications or research data, and sometimes tailor-made to a specific inquiry in a specialized area of concern.

There is no membership fee and no charge for most Infoterra services. Users merely submit their query to their NFP by mail, telephone, telex, fax, or personal visit. If a commercial database is used, or if costly on-line searches are made, the user will be charged at cost. However, if the inquiry comes from an official of a developing country, it may qualify for totally free service. It is a good method for obtaining specialized thematic information.

*International usage*

More than half of the 18,000 queries processed by the network in 1990 came from developing countries. Most inquiries in developing countries came from inside their borders, while most queries reaching NFPs in industrial countries came from abroad, including from other industrial countries.

*Sources of information*

In both industrial and developing countries, most sources are government departments, followed by industry, research institutes, and others. But in developing countries government sources account for over 80 percent of all information supplied, and industry accounts for less than 8 percent. This compares with a different profile in developed countries: less than 60 percent from government and over 25 percent from industry.
• Environment is not analyzed by the model and must subsequently be deduced based on flows and pollutants.

• Air pollution models can be used at several levels of detail. Some predict emissions based on detailed vehicle parameters and second-by-second speed data (drive cycles) which show the frequency of acceleration, deceleration, braking, and idling. These can be used to evaluate changes in vehicle technology, vehicle maintenance, traffic management, or fuel quality. Other models operate with aggregate traffic statistics and consider the dispersion of pollutants. An example of this type is Caline 4, also available from the US EPA. This model determines the air pollution effects of road projects and calculates the propagation (direction and speed, transport and deposit, etc.) of atmospheric pollutants. The data to be entered are traffic statistics (percentage of heavy vehicles), road geometry and topography, general climatology, and the initial concentration of pollutants in the air.

• Noise models estimate noise emissions for various traffic conditions and the sound levels experienced at various nearby locations, depending on intervening barriers and the nature of the ground and other surfaces which could absorb, reflect, or disperse noise. Micro Bruit is an example, distributed by the French urban transport research center CETUR (Centre d’Etudes des Transports Urbains). Micro Bruit forecasts sound levels taking account of the characteristics of the site, including terrain, buildings, utilities, obstacles, and noise propagation routes (figures 23.1 and 23.2). It also aids in the determination of dimensions for protection devices, such as barriers and embankments.

Many of these models are relatively inexpensive and can be used by nonspecialists for many applications. On the other hand, a full knowledge of model features, capabilities, and limitations can sometimes require considerable training and experience, which may become a considerably larger investment than the initial purchase price.
Computer-aided design and drafting (CADD) software

Preparation of preliminary and final design drawings for road project can take from a few months to several years, depending on the scale of the project and the amount, complexity, and diversity of data to be gathered. Computer-aided design and drafting software can help considerably in the efficiency of this process. Plan drawings of initial conditions are usually stored as a base “layer” in the CADD software, and separate layers are used for road designs and various features of specific interest, such as utilities (water, power, telephone) or drainage. These layers can be merged in various combinations to produce different types of drawing required for different planning, contracting, or management tasks.

Additional layers can be added for recording environmental features, for later preparation of thematic drawings for analysis or public presentation. These could identify site constraints such as soil engineering problems, water intake zones, historical monuments, protected sites, and natural resources.

CADD drawings can be updated as new information becomes available or as design concepts change. They make it easier for designers to examine different options and constraints, and they allow environmental planners to overlay various thematic constraints and sensitivities into a single map.

Geographic Information Systems (GIS)

A geographic information system uses a location referencing system to relate various types of database information to geographic locations and areas. The database information may be stored with different formats, software, and location criteria, but the GIS allows them all to be combined, displayed, and analyzed on a common map base. In many road agencies, for example, data on road inventory, road condition, traffic counts, accidents, and construction are managed by different departments and stored in different formats using different methods of identifying location. These can be brought together in a GIS system and combined with other data on population, income, agriculture, and a wide variety of demographic, social, and environmental factors.

The GIS expands the capabilities of individual databases by permitting query and analysis of the integrated data and geographic analysis of areas, distances, and volumes affected by various factors. Examples include the surface area of right-of-way or deforestation and the alignment of ditches. Display capabilities include the ability to “zoom in” on areas of interest, displaying more detail and highlighting features of specific interest, such as roads crossing wetlands or carrying more than a specified traffic volume.

Data entry for GIS systems is a major resource issue. The time and cost required depend on the data already available for a particular region: are there existing GIS databases being offered by GIS vendors or developed for other applications such as the agriculture, power, water, or mining sectors? Are base survey information and road maps already available in digital form, perhaps from computer-aided design software, digital field survey methods, or digital mapping from aerial photography?

- Map data will have to be digitized if it is not already available from the above sources. The level of detail (and hence effort) can range from simple outline drawings to a comprehensive map base showing considerable detail of topography and human development. To avoid a large initial time and cost barrier to starting up a GIS, it is often practical to begin with a very simple map base, which can be enhanced and expanded over time.

- Text data such as place names may need to be entered manually if it can not be automatically integrated using a scanner. However, much of the relevant text and numerical data will need to be related to geographic features through a process of adding location references to various database items. This can require considerable time and cost, including time needed for training and quality control.

While the initial cost of establishing GIS systems can be large, the value of the investment can extend far beyond a specific project or even a specific agency. The GIS database
provides a resource which can be used again for a wide variety of other applications and analyses covering the same physical region. In addition, storage of data in a GIS format:

- Enhances the value of data collected, by storing it in a very accessible format which can be readily visualized and understood by a wide range of people.
- Increases the potential for data quality, correction and updating. Errors in visual presentation of data are more likely to be noticed, both by professionals working with the data and others with local knowledge. Returning visual data to those responsible for its collection can also provide feedback on data quality and a greater interest in its end uses. A department or regional office providing accident data, for example, would receive in return a capability to visually display and analyze the data, in combination with additional data provided from other sources.
- Permits dynamic displays of relevant data to decisionmakers, professionals, and the public, modifying the issues covered and level of detail to match the needs of the audience and specific questions which may arise during discussion.
- Allows prompt and user-friendly access to data for technical queries which may arise from time to time, with less reliance on database specialists.

GIS systems can thus protect and enhance investments in data on roads and the environment, extending their useful life and making them available to a wider audience.

**General Issues in computer applications**

The advantages of computers in environmental aspects of road projects include access to a wide range of information sources, immediate availability of information, and ease of updating with new environmental data, road plans, or mitigation options. Computers also allow data to be combined in various ways; for example, to show baseline conditions, predicted impacts on various aspects of the environment, and subsequent changes experienced in practice. Table 23.1 shows how computers are used at various stages of environmental assessment.

Planning and budgeting for computer applications must take account of the needs for training, technical support, skills backup and retention over time, data entry, and data updating and quality control over time. In addition, provision must be made for ensuring future access to the data and software, including storage, documentation, and technical support for end users.

Computer hardware requirements for all of the applications discussed in this section can be met with typical personal computers currently available at the time of writing. Some applications will work best with higher-quality processing power, graphics screens, and memory capacity available on personal computers, and some may require peripheral equipment such as digitizers, scanners, and color printers or plotters.

| TABLE 23.1 |
| Use of computers in various stages of the environmental assessment process |

<table>
<thead>
<tr>
<th>Environmental intervention</th>
<th>Role of information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental assessment report</td>
<td>Summarize existing conditions and potential project impacts and options</td>
</tr>
<tr>
<td>Mitigation plan</td>
<td>Identify mitigation options, design alternatives, and implementation issues</td>
</tr>
<tr>
<td>Environmental monitoring</td>
<td>Gather information to confirm or refute the predicted impacts and modify mitigating measures as required</td>
</tr>
</tbody>
</table>
Bibliography

Arc News. Quarterly publication of the ESRI company, producing the ARC/INFO GIS.


Other sources of information

Further information may be obtained from numerous national and international organizations which have an interest in roads and environment, including the following:

United Nations Environment Program (UNEP)
Tour Mirabeau, 39-43
Quai André Citroen
75739 Paris, Cedex 15, France

Organisation for Economic Cooperation and Development (OECD)
Road Transport Research Program
2 rue André Pascal, 75775 Paris, Cedex 16, France

Permanent International Association of Road Congresses (PIARC)
27 rue Gueneaude, 75006 Paris, France

Australia: Victorian Roads Corporation (VicRoads)
60 Denmark Street, Kew, Victoria, Australia, 3101

Canada: Canadian International Development Agency (CIDA)
200 Promenade du Portage, Hull, Quebec, K1A OG4 Canada

France: Service d'Etudes Techniques des Routes et Autoroutes (SETRA)
46, avenue Aristide Briand -B.P 100 92223, Bagneux, France

Japan: Japan International Cooperation Agency (JICA)
Shinjuku Mitsui Gldg. 46/FL
1-1, Nishi-Shinjuku, 2-Chome, Shinjuku-Ku, Tokyo 163-04, Japan

Sweden: National Road Administration
S-78187, Borlange, Sweden

United States: Federal Highway Administration
400 Seventh Street, S.W.
Washington, D.C. 20577, U.S.A.

United Kingdom: Overseas Development Administration
94, Victoria Street, London, SW1E 5JL, U.K.

Other documents which may be useful for readers of this handbook include:

- Manual of Environmental Appraisal, Overseas Development Administration, U.K.