Lecture 8

Environmental Management Techniques

STRUCTURE

OVERVIEW

In Units 4 to 7, we discussed environmental management tools. In Unit 8, we will discuss some related environmental management techniques. We will begin the Unit by discussing environmental monitoring. We will then explain how modelling helps in applying the environmental tools in real-life situations for quantification of impacts, prediction of scenarios and simulation studies. We will also discuss other techniques such as sensitivity analysis, remote sensing, environmental profiling, environmental technology and risk assessments and eco-mapping. We will then introduce you to the techniques that can be adopted in the urban contexts. Finally, we will discuss the importance of environmental education, i.e., a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges and fosters attitudes, motivations and commitments to make informed decisions and take responsible actions.

LEARNING OBJECTIVES

After completing this Unit, you should be able to:

- state the processes involved in monitoring, modelling, sensitivity analysis, remote sensing, environmental profiling, technology assessment, risk analysis and social impacts;
- use these techniques where relevant;
- carry out eco-mapping;
- discuss the need for and the role of environmental education in environmental management.

8.1 ENVIRONMENTAL MONITORING

Environmental studies often require information on physical, chemical, biological, economic or social aspects of particular environments. These can be obtained from a monitoring programme involving surveys, measurements and data collection activities. A monitoring programme, thus, helps establish baseline information and data for describing the present situation of an area likely to be impacted by a proposal.

Monitoring may involve sampling of air, water, vegetation and soil, and these data collection programmes should be planned to obtain the greatest value from the data, which is often expensive to collect and process. Care should be taken to classify, analyse and store data for easy retrieval, so that it can be useful as baseline or reference data for other assessments.

In environmental management, monitoring has a role to play even after the completion of environmental studies and the subsequent implementation of the projects. In many cases, for example, some impacts may remain uncertain, as there may be insufficient time or resources to assess these with complete confidence. If when applying the precautionary principle, the likely adverse effects of a project appear to be low and to be outweighed by the benefits, a regulatory authority may permit the project to proceed, but with a requirement for monitoring the effects.

The owners of the project are, therefore, obliged to carry out a monitoring or surveillance programme continuously or at defined intervals, and to report the results to the regulatory body. If adverse effects beyond those anticipated in the original environmental impact assessment become apparent, remedial actions must be taken. However, in situations where suitable remedies are not available, it is possible that the projects are terminated.

A post-implementation monitoring of a project may involve audits such as:

- Implementation audits to determine whether the recommendations or requirements in a EIS were implemented.
- Project impact audits, to determine the actual impacts of a project, independent of the predictions made.

- Predictive techniques audits, to assess the predictions made in the EIS and the methods of prediction used by comparing actual outcomes with forecasted ones. (This will aid future studies.)

Before you read further, note the distinction between monitoring, survey and surveillance programmes given below:

- **Monitoring:** A long-term, standardised measurement programme involving observation, evaluation and reporting of part of the environment in order to define status and trends.
- **Survey:** A finite duration, intensive programme to measure, evaluate and report the quality of part of the environment for a specific purpose.
- **Surveillance:** A continuous, specific measurement programme involving observation and reporting for the purpose of environment management and operational activities.

8.2 ENVIRONMENTAL MODELLING

Before we discuss environmental modelling, let us first explain what modelling means. A model is a representation of real-life problems or situations. It copies significant attributes of a real prototype but is simpler and is easier to build, change or operate. Put differently, models are basic tools in science, engineering, business and various forms of planning. They can be applied to situations or systems, which are both existing and non-existent. For example, suppose that we are to assess the environmental impacts of releases of heated water from a proposed thermal power plant into a shallow lake. To assess the impact, do we have to build a power station and deliberately release varying amounts of heated water, as an experiment? Given the huge efforts, great costs involved, etc., this is unwise to do. Furthermore, this will cause the very environmental damage that the planning exercise is trying to prevent. To assess impacts, it is obviously better to use a model of the system.

Essentially, models allow us to extrapolate from the existing systems and knowledge to analyse potential situations. They are only useful to the extent that they accurately model the real world. Models can be constructed from logic or rational assumptions, scientific theories and information about similar situations or operations.

The model structure may be set up to search for an optimal answer (as in linear or dynamic programming models) or to generate possible solutions (e.g., stochastic models). The great majority of models, however, just stimulate the behaviour of a system. Variations can be explored by running the model several times, changing inputs or other features. There are many kinds of models such as statues, model aeroplanes, scientific theories, hydraulic laboratory models and computer programs. We can classify models into the following:

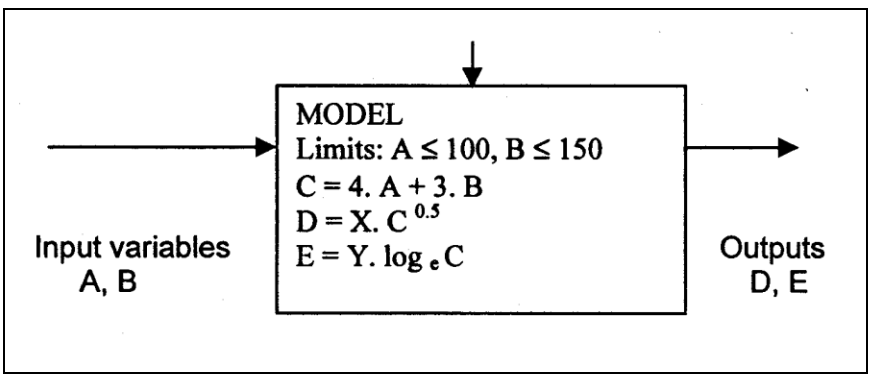
- Iconic models, which have similar attributes to the prototype, e.g., a model-racing car.
- Analogue models, where some aspects of the model are analogous to the prototype, although they differ physically, e.g., flows of heat, electricity and ground water act similarly, and electric analogues have been used to model ground water flows.

- Symbolic or mathematical models, which describe physical situations using abstract representations such as diagrams, equations, sets of calculations or computer programs.

Mathematical model

The most widely used types are mathematical models, which use logical relationships, rules, variables, equations, parameters and algorithms (i.e., sets of linked equations). These describe systems, made up of various parts and connections, rather than self-contained entities. Figure 8.1 illustrates a simple mathematical model:

Figure 8.1
Simple Representation of Mathematical Model



The mathematical model of the type depicted in Figure 8.1 above may describe processes such as:

- Pollution of an area of land by chemicals carried by groundwater, with pollutant and water quantities as inputs, soil properties as parameters, pollutant concentrations at various locations as outputs and a mathematical description of groundwater flows as the model. (Calculations will proceed for various time steps, say, at daily intervals, and, therefore, there will be sets of input variables, rather than single values.)

- A cash flow analysis with receipts and payments as inputs, discount rates as a parameter, net present value as an output and compound interest equations as the model.
- The effects of development and environmental degradation on land values, with development and pollution levels as inputs, indices of social reactions as parameters and land values as outputs and relationships involving benefits of development, disadvantages of pollution, public perceptions and land values as the main model.

Other examples of the above are oxygen sag in a river, operation of an industrial plant, econometric models describing consumer responses to changes in energy prices and ecological changes in an altered environment.

You must note that:

- Models can be much more complex than the simple structure shown in Figure 8.1, with iterations and feedbacks. A steady-state model can describe static situations or snapshots of a system at a particular time. Situations changing with time can be modelled by unsteady or dynamic models, which work with a series of time steps. These usually employ the calculated outputs at the end of one time step as inputs at the beginning of the next step. Probably, the most famous models are those used by the Club of Rome (Meadows et al., 1972, Meadows et al., 1992), which stimulated the future of the Earth, exploring global scenarios of population growth, industrial production and environmental degradation.
- Models may be purpose-built for a particular application, or general models which often use proprietary computer programs. Examples of general models are those describing storm water pollution transports, such as the Storm Water

Management Model (SWMM) from the U.S. Environmental Protection Agency and the Storage, Treatment, Overflow Runoff Model (STORM) from the U. S. Army Corps of Engineers. When general programs or packages are used, you should realise that two models are involved – the standard computer model which provides a *shell* into which a model for a particular situation (expressed in the input data file) can be fitted.

- While most computer models were written in languages such as FORTRAN in the past, many modellers are now likely to use spreadsheet programs such as Lotus 1-2-3 and Excel. These offer facilities for basic stimulation, special functions such as random number generation for Monte Carlo Analysis, regression and other statistical tests and easy presentation of results as charts and graphs. Microcomputers provide adequate computer power for most modelling applications.
- Models are ineffective without data and calibration. Model results are sometimes accepted without adequate scrutiny because they are generated through a computer. The axiom *rubbish in – rubbish out* applies to all computer programs. Computer generated results must therefore analyse critically and should be checked for consistency and logic, and if possible, validated against additional data.

The accuracy of a model depends upon the following, in order of importance:

- amount of data used to build and operate the model;
- experience or skill of the analyst;
- quality of the model.

Modelling exercises involve prediction of uncertain system behaviour, usually during some future period. Forecasting is, therefore, necessary in environmental management, as it helps in prediction of future periods. Growth modelling is required in areas such as estimation of future population for urban area, growth of fauna in forest, etc. We will discuss these two types in Subsection 8.2.1 and 8.2.2, respectively.

LEARNING ACTIVITY 8.1

List the input variables, system parameters and output parameters you would consider for developing a model for the estimation of the impact of industrial sources of noise on nearby habitations.

Note:
a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.

8.2.1 Forecasting modelling

It is important for you to note that the scope of forecasting techniques is limited. For example, the longest time for a reasonable population projection is one decade, whereas for economic projection the timeframe is, at the most, 12 months. Long-term forecasts by expert think tanks are usually wide off the mark. In addition, all forecasts can be invalidated by some drastic event, such as a war or a natural disaster. Thus, we should have a healthy skepticism about forecast results, and apply checks on them.

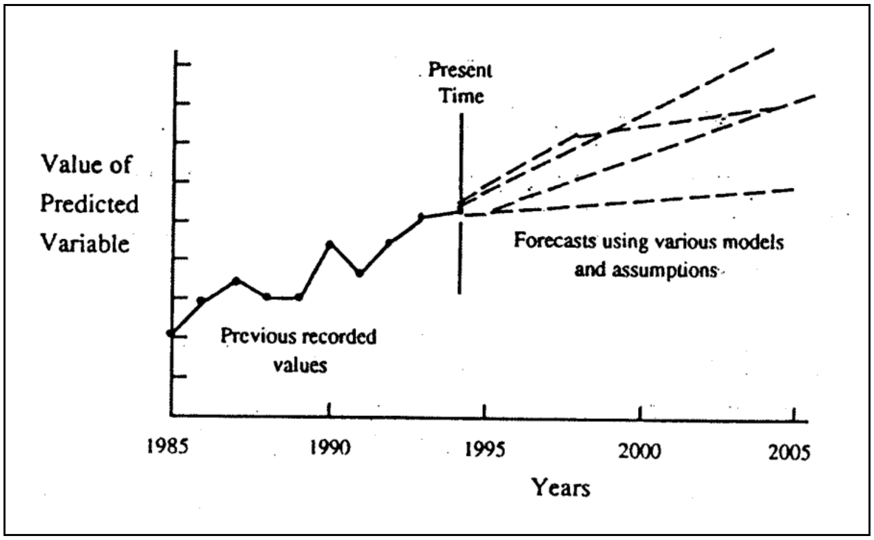
The factors/data needed, among others, to make a forecast are:

- Information on the situation being forecast, preferably past records of the main factor of interest and related factor.
- A model of the system or situation, which could be a simple concept, such as the input-output system in Figure 8.1, or a full scientific model based on physical description and theory, such as the computer models used in weather and climate prediction.

Forecasting can be done on the basis of experience of judgement, but it is better to have some explicit model or basis. These can be causal or explanatory, seeking to describe the processes producing the phenomenon being predicted, or non-causal, considering results numerically or statistically, but not trying to define underlying processes.

Figure 8.2 shows the forecasting problem for a particular variable using past record of values for extrapolation:

Figure 8.2
Extrapolation of Past Values: An Illustration



Note that the forecasting model illustrated in Figure 8.2 is used in population forecasting based on past census data.

A systematic forecasting may use such mathematical models as linear, multiple and non-linear regression relating future values to the past record or time series of values, smoothing using simple and double moving averages, exponential smoothing, etc., filtering and Box-Jenkins.

The literature is replete with mathematical forecasting models. However, to use these models properly, it is necessary to set up databases of past records.

Note that simple regression techniques are useful to establish a relationship between the value and time, which can be extrapolated to make predictions. Smoothing techniques help reduce the variability of data. Moving averages, for example, replace each value with the mean of this value and the values occurring immediately before or after it, and this allows us to work with a reduced variable set of values for extrapolation. Thus, we may average 3, 5 or more values. Spreadsheet programs for computers now offer facilities for regression, time series analysis and smoothing.

When data availability is limited, one of the right models is the cause-effect model. Causal model include factors, which are known to influence the variable being considered. For example, the quantity of rice sold by an agricultural co-operative at the end of a harvest may be related to the cost of fertilizer, the price of rice, the price of wheat (a competing product) and the rainfall for the growing season.

An alternative to mathematical modelling is to seek the opinions of experts. The Delphi technique and other procedures combine the views of experts in a series of structured meetings where alternatives and scenarios are presented, debated and consensus sought. These procedures can be employed for forecasting, as well as for general policy and decision-making.

8.2.2 Growth modelling

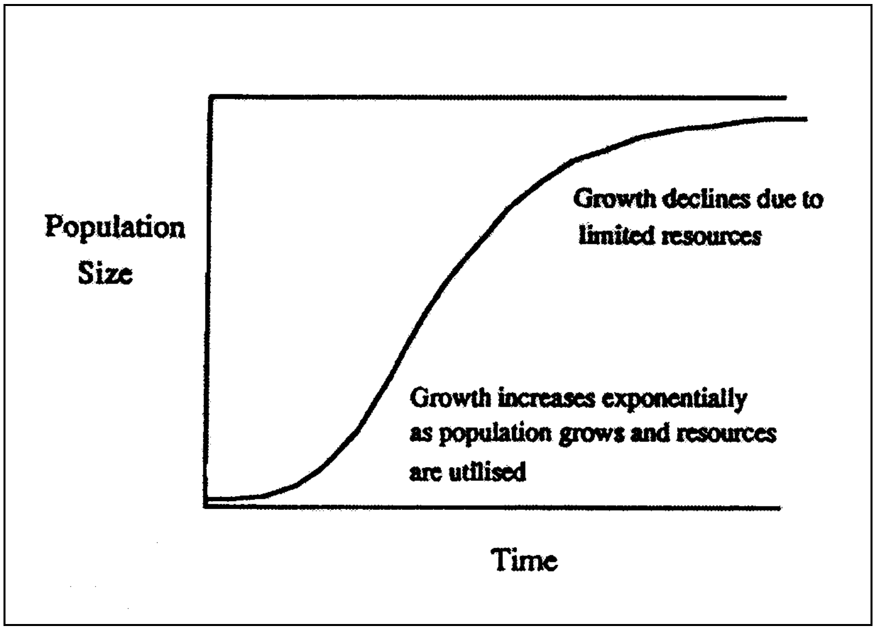
The two important methods in growth modelling are exponential growth modelling and logistics growth modelling. Exponential growth occurs in situations where the increase in some quantity is proportional to the amount currently present. The growth can be predicted either as a discrete function, i.e., year by year or as a continuous function.

Suppose the present population of a city is 1 million and it grows by 2% per year, the population in the following year will be 10,20,000 (*10,00,000 + 0.02 x 10,00,000*). After two years, this will be 10,42,000 and so on. Mathematically, we can represent this as:

> *Population in year t + 1 = Population in year t + growth rate x population in year t.*

Alternatively, we can represent this in terms of logistic S-curves as illustrated in Figure 8.3 below:

Figure 8.3
Logistic S-Curve as a Limitation on Populations



Biologists successfully use logistic curve models to model populations of many organisms including protozoa, yeast cells, etc. Such models describe the rate of change in population as a function of present population, natural growth rate and carrying capacity of the ecosystem. Mathematically, this is represented as:

$$\frac{dN}{dt} = rN(1 - \frac{N}{K})$$

where N is population size; r is growth rate and K is carrying capacity of the environment.

Notice that when N is less than K, the rate of change of population is proportional to population size. That is to say, the population grows exponentially with growth rate r. As N increases, the rate of growth slows down, and eventually, as N approaches K, growth stops altogether and the population stabilises at a level equal to the carrying capacity. The factor $(1-\frac{N}{K})$ is often called the environmental resistance, i.e., as the population grows, the resistance to further population growth continuously increases.

The solution to the above equation is:

$$N = \frac{K}{(1+e^{-r(t-t^*)})}$$

Note that t^* corresponds to the time at which $N = K/2$. Substituting $t = 0$, lets us solve for t^*:

$$t^* = \frac{1}{r} \ln(\frac{K}{N_0} - 1)$$

Where N_0 is the population at a time $t = 0$.

In the usual application of logistics growth equation, the growth rate is known at $t = 0$, but this is not the same as the growth rate r. To find r, let us introduce another factor $R0$. Let $R0$ = instantaneous rate of growth at $t = 0$. If we characterise the growth at $t = 0$ as exponential, then:

$$(\frac{dN}{dt})_{t=0} = R_0 N_0$$

But

$$(\frac{dN}{dt})_{t=0} = rN_0(1-\frac{N_0}{K})$$

And so

$$r = \left(\frac{R_0}{1-\left(N_0/K\right)}\right)$$

Using this equation, we can use quantities that are known at $t = 0$, namely the population size (N_0) and the population growth rate (R_0), to find appropriate growth factor (r).

The logistic curve can also be used to introduce another useful concept in population biology called the *maximum sustainable yield* of an ecosystem. The maximum sustainable yield is the maximum rate that individuals can be harvested (removed) without reducing the population size. Let us consider fish harvesting as an example. If the fish pond is at its carrying capacity, there will be no population growth, and, therefore, any fish removed will reduce the population. In other words, the maximum sustainable yield corresponds to some population size less than the carrying capacity. In fact, since the yield is the same as *dN/dt*, the maximum yield corresponds to the point on the logistic curve where the slope is at a maximum. We can find that point if we set the derivative of the slope equal to zero. The slope of the logistic curve is given by:

$$\frac{dN}{dt} = rN\left(1-\frac{N}{K}\right)$$

Setting the derivative equal to zero gives:

$$\frac{d}{dt}\left(\frac{dN}{dt}\right) = r\frac{dN}{dt} - \frac{r}{K}\left(2N\frac{dN}{dt}\right) = 0$$

This yields:

$$1 - \frac{2N}{K} = 0; \;\; N = \frac{K}{2}$$

This means if the population growth is logistic, then the maximum sustainable yield will be obtained when the population is half the carrying capacity.

In any analysis modelling, certain degrees of uncertainty are unavoidable. However, by carrying out sensitivity analyses, we can determine the degree of uncertainty. Let us discuss it next. But, first, work out Learning Activity 8.2.

LEARNING ACTIVITY 8.2

Suppose the human population follows a logistic curve until it stabilises at 15.0 billion. In 1986, the world's population was 5.0 billion and its growth rate was 1.7%. Calculate when the population will reach 7.5 billion > 14 billion.

Note:
a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.

8.3 SENSITIVITY ANALYSIS

Any analysis, be it an environmental model, a cost-benefit study or other investigation, will involve a number of input factors having different degrees of uncertainty. These will influence the outcomes of the study to varying extents. In an input-output process (see Figure 8. 1), we usually select the inputs as the most-likely values. The relative responses of outputs to changes in inputs are termed by their sensitivity. That is to say, if large changes in an input produce insignificant changes in an output, the output is insensitive to the input.

A basic test of sensitivity is whether a percentage change in an input factor produces a higher or lower percentage change in an output. For example, consider now the model shown in Figure 8. 1. The factors in the analysis can be seen as inputs (A, B), and the outcomes as outputs (D, E). If the parameters were set at $X = 1.1$ and $Y=1.9$, and the most likely inputs were $A = 75$ *and* $B = 102$, the outputs will be $D = 27.1$ and $E = 12.2$.

Now, suppose that input A is considered to be accurate to ±40%, and input B to be accurate to ±25%. The limits for A may, therefore, be from 45 to 105, and for B from 76.5 to 127.5. Taking the highest and lowest sets of values, we can repeat the calculations. The low values of A and B lead to outputs of $D = 22.3$ *(-18%)* and $E = 11.\ 4$ *(-7%)*. The high values of inputs (with A truncated from 105 to 100) will give $D = 30.8$ *(+44%)* and $E = 12.7$ *(+4%)*. The percentage figures show that the outputs are relatively insensitive to the 25% changes in inputs. This is due to the square roots and log functions in the equations for D and E. Other relationships may amplify the changes in inputs and accordingly give sensitive responses.

The extent of the change in an outcome, such as a level of CO_2 emissions or a net present value, NPV, relative to the change in the input, can be used as a mathematical indicator of sensitivity, similar to the concept of elasticity in microeconomics. Some mathematical programming procedures (e.g., linear programming) calculate sensitivity factors.

Sensitivity analysis is a powerful, yet simple, technique for determining the effects of individual factors and their variations on the overall results of an analysis. It can be applied to any analysis, which can be visualised as system inputs and outputs, and merely involves the repetition of calculations. This process is greatly facilitated, if all or part of the analysis can be set up on a computer. Spreadsheet programs (Excel and Lotus 1-2-3) derive their popularity from their ability to carry out sensitivity studies with ease.

In financial studies, for example, the numbers can be set out in a grid to represent a cash flow or a spending budget, and indicators such as NPVs or gross profits can be calculated by the formulae associated with particular grid locations. The alteration of any number in a grid causes all values determined by formulae to be re-calculated. Similar calculations can be performed with models of other processes. In short, the most basic use of sensitivity analysis is exploring "What if?" situations.

Note that there is no formal procedure for sensitivity analysis. For example, it can be applied by:

- examining factors one at a time and determining the variation in outcomes due to changes to a single factor, keeping the others at their most likely values;
- taking the best or worst estimates of all factors to see how a system performs under extreme conditions (If it performs favourably when all factors are set at their most unfavourable values, the analyst can be very confident about outcomes.);

- varying a factor sufficiently to cause a reversal of the outcome given with its most likely value. (For example, if a transportation project produces pollution in excess of some regulatory standard, the analyst could determine how far the process must be modified to meet the standard. This technique requires an iterative search, and is probably only practical if an analysis has been computerised.)

It is useful to carry out sensitivity analyses at a preliminary stage of a large study to identify which of the factors involved have the greatest bearing on results. Particular attention can then be paid to data collection and estimation, so that they can be estimated as accurately as possible. The less important factors need only be estimated approximately.

LEARNING ACTIVITY 8.3

In the prediction of impacts of combustion of coal in thermal power plant on surrounding air quality, describe three parameters which you would consider in sensitivity analysis.

Note:
a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.

Following our discussion of sensitivity analysis, which is important in any kind of terrain study, we will next discuss the application of remote sensing and GIS in environmental management. Modelling and sensitivity analysis find immense use in such applications.

8.4 APPLICATION OF REMOTE SENSING AND GIS IN EM

Benefits of harnessing the new developments in high technology areas like space technology and information technology for sustainable development have been well recognised and many developing countries are looking towards assimilating these technologies as part of their developmental plans. Satellite remote sensing integrated with Geographical Information System (GIS) technology provides a tool for addressing the issues of spatial reference in enhancing the quality of life and sustainable development.

Geographical Information Systems are computer aided decision support and planning tools, which integrate data from maps (spatial data) and other auxiliary data (attribute data) for a geographical area of interest. They can be used to create and maintain geographic databases and are eminently suited for what-if-analysis in any planning related activity. GIS applications are developing rapidly. A GIS application is able to provide many simulated results, which help in making informed decisions. These simulated results also help decision-makers in addressing such questions as the following:

- Where is the most polluted area in the industrial area and how much is the total?

- Where is the exact location of the polluted rivers and total number of industrial units along the river?
- How many premises are violating the environmental norms?
- Where are the projects located that need to be considered in an environmental impact assessment (EIA)?

The basic advantage of the GIS technology is its ability to manage and integrate with the existing database. This means that at any point in time we are able to see not only the spatial data but also the database. For example, by referring to the colour codes displayed within a map on a GIS application, we will know that grey area is a polluted area and the green area is free from pollution. At the same time, the presentation of database related to the spatial data can also be shown.

The implementation of GIS for the purpose of controlling and monitoring development involves the stages of data gathering and updating; development of GIS database; development of user interface and application of GIS database.

Once the GIS package integrates the spatial and attribute data, the planner has a powerful tool, which can be used for information dissemination or analysis. By querying the geographic database in several ways, the planner can present the available information in a variety of formats (e.g., printed tabular reports, graphically as map display and map outputs on paper). The analysis capabilities of a GIS package allow the planner to address what-if questions and work out a variety of action plans in a scientific manner.

A number of problems can be solved by geographic analysis. Typical examples include township development; relationships between agricultural parameters (e.g., yield and salinity), land capability analysis, site locations for facilities and environmental problems (animal migration).

Remote sensing and GIS technologies play a vital role in urban and regional planning, resources monitoring and allocation and environmental management. India is one of the few countries in the world that has made remarkable progress in space technology. India has launched a series of operational remote sensing satellites providing high quality remote sensing data to several parts of the world. By integrating remote sensing and GIS methodologies, India has carried out a number of operational projects at national level in the areas of resources planning and management. In response to rapid developments in computer hardware, graphic display systems and spatial theory, GIS technology is achieving wide spread popularity among the administrators, managers, line department personnel and academia.

In Sections 8.5 to 8.9 we will discuss some environmental tools that can be used in urban contexts.

8.5 ENVIRONMENTAL PROFILE

Life in cities depends upon a wide variety of development activities such as industry, commerce, transportation, construction, households, etc. These activities depend upon, as well as damage, environmental resources such as land, water, air and ecological systems.

Environmental profile (EP) is normally the first project activity to be undertaken for a city level project implementation. It brings together information about the city's development sectors and activities, its environmental resources and hazards and management systems in a way that allows a systematic analysis of how development and environment interact. In this way, EP not only highlights and elaborates the key environmental issues facing the city, but also puts them equally into the appropriate development and management context. It also identifies the different groups, organisations and stakeholders, which have important (and often conflicting) interests.

Two main purposes of EP are:

(i) To provide a systematic overview of a city's development activities and how they interact with the city's environmental resources.

(ii) To identify and mobilise stakeholders by being a source of relevant information and a process of its preparation.

The four main chapters of EF are city introduction, development setting, environment setting and environmental management. We will discuss these, next.

City introduction

This should give a highly summarised and selective introductory information about the city including its geography and physical setting, social characteristics and economy. The purpose of this chapter is to provide information about the city, which is relevant and important for understanding the other chapters that follow. This chapter includes one or two A4 sized basic maps.

Development setting

This chapter examines environment development relationships from the point of view of development activities. It discusses the development activities of the city (e.g., manufacturing, mining, fisheries, transport, housing, etc.) The main purpose is to describe the use of environmental resources by each activity sector in terms of type, quantity and quality of resources used. For example, local manufacturing industry may consume groundwater as part of its production process and may also use waterways and the atmosphere for getting rid of the waste. This chapter also analyses the impacts of each sector on environmental resources and examines environmental hazards.

Environment setting

This chapter examines the city's environmental resources and the ways in which the city's activity sectors make use of and have impacts on these resources. In the context of the EP, environmental resources are primarily those things arising from the physical world, which are used to support urban life and development. This means air, water, land (and the living and non-living organisms in them) as well as areas of special ecology and special human-made environments such as cultural and historical buildings. This chapter analyses each of the environmental resources separately in the following five sub-sections:

(i) **Characteristics of the resource:** This Subsection describes the resource in terms of quality, quantity and different ways in which it is used.

(ii) **Use of resource by activity sectors:** This Subsection discusses the use of the resource by all activity sectors together with respect to level of extraction, consumption and depletion.

(iii) **Impacts on the resource from activity sectors:** This Subsection discusses the impact of the activity sectors on the resources, including impacts of pollution and damage.

(iv) **Competition for use of the resource:** This Subsection discusses the conflict among the activity sectors in the use of the resource.

(v) **Management arrangements:** This Subsection discusses institutional arrangements or initiatives, including the organisation's responsible, special arrangements such as commissions, projects, etc., to help manage the resource.

Environment management setting

This chapter has three main sections: key stakeholders, urban management structures/institutions and strengthening urban and environmental management. The purpose of the first section (i.e., key stakeholders) is to identify and discuss only those stakeholders that play significant roles in urban development and urban environmental management. The stakeholders can be classified into the public sector, community sector, private sector and other interest groups not covered by the other groupings. When describing the various stakeholders, the chapter generally gives a brief account of their activities and roles. This account pertains to the information, knowledge and technical expertise they possess or have access to; the extent to which they are involved in decision-making, policy formulation and policy coordination and their involvement in the implementation of the city's development and environmental policies, programmes and projects.

The second section (i.e., urban management structures/institutions) gives an overview of the city's organisational structure using four headings, i.e., basic organisation and structure; information, knowledge and technical expertise, and how it is applied and shared; process of decision-making, policy formulation and coordination and policy implementation. The third section (i.e., strengthening urban and environment management) discusses current or planned initiatives and efforts to strengthen the city's urban and environmental management systems and to increase local abilities to plan, coordinate and manage sustainable urban development.

In Section 8.5, we described EP as a tool that brings together information about a city's development sectors and activities, its environmental resources and hazards and management systems in a way that allows a systematic analysis of how development and environment interact. In Section 8.6, we will describe another tool, i.e., environmental technology assessment for urban contexts.

8.6 ENVIRONMENTAL TECHNOLOGY ASSESSMENT

An environmental technology assessment (EnTA) is an analytical tool used to help understand the likely impact of the use of new technologies in terms of costs, monetary benefits, environmental effects and social and political impacts. It focuses on the analysis of effects on the environment, specifically on human health, ecological systems and resources. It is explored as an analytical tool, designed to ensure that decision-making processes related to technology adoption, implementation and use are sustainable.

Decision-making is normally tiered in a sequence of multiple decisions. Multiple decisions often progress from a strategic or policy level, through plans and programmes to specific project level decisions. It is argued that more conventional analytical tools such as environmental impact assessment (EIA) and social impact assessment (SIA) fail to address issues at the higher tiers of decision-making and that an EnTA, a flexible approach to technology related decision-making, is well positioned to fill this gap.

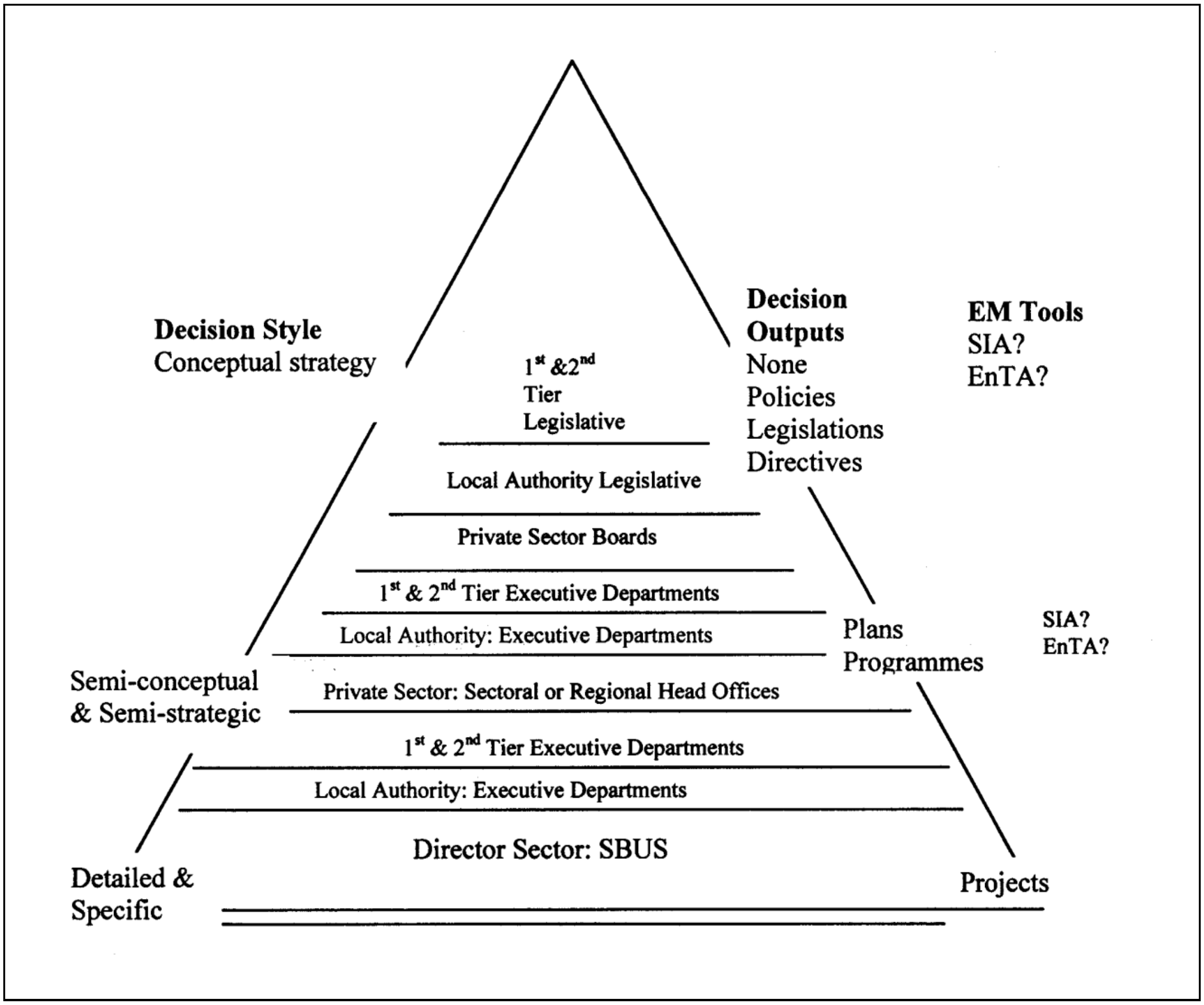
Potential users and scope of EnTA

The informal voluntary nature of EnTA is most appropriate at the politico-strategic decision-making levels within the urban management context. As a strategic decision-making philosophy that enhances sustainability rather than a prescribed process, an EnTA is aimed at administrators providing strategic and policy level guidance.

Hierarchical decision-making at local authority level

Decisions on technology adoption, implementation and use at local authority levels are often one-shot events. Instead, they are characterised by a multiple sequence of decisions made across a tiered hierarchy, a process that is called *disjointed incrementalism*. The decision-making sequence starts with conceptual or strategic policy type decisions at the apex, followed by semi-conceptual or semi strategic plans and programmes, culminating in detailed or specific project related decisions as shown in Figure 8.4:

Figure 8.4
Specific Project Related Decisions



As illustrated in Figure 8.4 above, decision-making at the apex is often confined to broad, strategic, policy type decisions, which are frequently politicised. While inadequate information may increase the uncertainty level, which is usually characterised by time constraints, information requirements are limited to conceptual and generic directions. More often than not, decision outcomes represent policy statements that are intended to give direction to lower tier decisions. Critical concerns regarding the relationship between assessment tools and decision-making at the top tiers include the following:

- EIAs are seldom done for decisions at this tier of decision-making.
- EIAs are not designed to meet the challenges of decision-making at this tier in part due to time constraints.
- EIAs are often commissioned too late to address issues that have been resolved at the top tier.
- EIAs are very seldom used to challenge policy level decisions with the result that many issues are foreclosed when they are conducted.

Comparison of EnTA and EIA

A comparison between EnTA and EIA explores both differences and similarities. Table 8.1 below gives the differences between EnTA and EIA:

Table 8.1
EnTA and EIA Differences

EnTA	EIA
Strategic nature	Project specific
Conceptual	Detail
Not legislated	Often legislated
Flexible procedure	Formal procedures
Greater simplicity	Increased rigour
Reflect strategic decision	Reflect project design & planning
Value judgements	Specific facts
Based on 'guestimates'	Based on science
Scenarios	Specific predictions
Increased uncertainty	Increased certainty
May be used as an internal tool	Often an open and participative process
Focus on suitable service delivery	Focus on change

Table 8.2 below gives the similarities between EnTA and EIA:

Table 8.2
EIA and EnTA Similarities

Feature	EnTA and EIA
Impact identification and assessment	This is the core element in both
Future-orientation	Both predict/forecast
Technological focus	Sometimes EIA focus on technology
Comprehensive	Both aspire to be as comprehensive as possible
Scale	This is a variable in both

Benefits of EnTA

EnTA is a flexible, informal and voluntary tool that defines an appropriate approach to sustainable decision-making. EnTA should be used to ensure increased eco-efficiency and sustainability of both technologies. Eco-efficient technologies or environmentally sound technologies perform better across all the dimensions influencing sustainability of technology selection, adoption and use, as well as the various phases of the project execution cycle. Improved eco-efficiency of technologies may be evaluated in terms of parameters such as improved environmental sustainability (i.e., improved resource and energy consumption, reduced emissions and effluents, reduced wastes and improved safety and health profiles), increased net social benefit, equity and empowerment, improved economic sustainability, improved financial sustainability, improved technical sustainability and improved institutional capacity.

Major in-roads and applications

It is not possible to report on specific EnTA case studies, as EnTA is primarily a voluntary and internal tool that is used by organisations to ensure that technology related projects are guided by sustainable policy decisions before more project specific environmental impact assessment (EIAs), hazard and operation ability studies (HAZOPS) or risk assessments are done.

However, an entity like the Development Bank of South Africa has done EnTA-like analysis of prospective borrowers for implementing water treatment technologies. A large petrochemical company has also internalised hybrid EnTA and EIA principles into their project appraisal procedures.

Note that because EnTA, as a philosophy or an approach to technology adaptation processes, is internalised into the decision-making process, it is not documented in the same manner as EIAs, which have a distinct approval phase.

8.7 ENVIRONMENTAL RISK ASSESSMENT

Risk may be defined as the combination of the probability of occurrence of an event and the possible extent of its adverse effects and consequences in terms of economic loss or human injury. Risks can relate *to hazards to humans* from natural disasters, and events such as traffic accidents and diseases and chronic dangers such as cigarette smoking. Health risks such as probabilities of contracting a particular disease are environmental hazards in the sense that they arise in our surroundings. They may be connected with projects such as development of industrial plants or particular production processes, and must be included in environmental assessments. Economic risk is yet another type of risk. Fairly sophisticated mathematical techniques have been developed for analysing economic risks and introducing probabilistic risk assessments into cost-benefit analysis. Other forms of risk may relate to hazards from industrial processes, safety of workers and effects of emissions on natural systems, flora and fauna. Ecological risk is handled using similar techniques as human health risks.

Note that risk involves both uncertainty and severity of damage. There will be no risk, if one knew the exact time, place and nature of an adverse event, and there would be no risk, if no damage occurred. Mathematically, risk can be expressed as:

> *Risk = Probability of some event x seriousness of its consequences.*

Risk analysis and risk management have been widely used in insurance and business decisions for many years, and more recently, as a basis for environmental decision-making. Risk analysis is a systematic use of available information to determine how often specified events may occur and their likely consequences. Its purpose is to identity the causes, effects and magnitudes of risk and to provide a basis for risk assessment and treatment. Risk management is the systematic application of managerial policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring risks.

Having said that, let us now focus on risks related to industrial production processes.

8.7.1 Environmental risk management in industry

Environmental risk management in companies is a fairly recent phenomenon. Generally, risk management has been associated with insurance and the recovery of financial losses in the event of unexpected disasters. But, catastrophic accidents have increased in number in the last decade, dramatically underlining the fact that there is a serious and growing worldwide problem that must be faced.

Depending on the timing of the damage, risks can be immediate or delayed. The risk can also be *voluntary* (e.g., smoking, driving, etc.) or *involuntary*, (e.g., living close to a potentially dangerous industrial plant). Furthermore, risks can be represented in two different forms, namely, individual risk and societal risk. Individual risk is the frequency with which an unprotected person is affected by a specific type of damage. Societal risk is the relationship between the frequency of an accident and the number of people injured or killed.

A situation of risk can involve an opportunity for success as well as a prospect of failure. If the risk can result in failure only, it is a *negative risk* and is usually defined as static (e.g., the risk of a fire in a company's properties). A risk that can result in both success and failure is defined as a dynamic risk (e.g., buying shares in the stock market). Environmentally related risks are mostly limited to situations where an event can only cause environmental degradation and/or adverse human health effects, and they must therefore be considered as static risks.

Companies are built and managed on the whole concept of risk. No matter how big or small a business decision may be, it is based on the degree of risk for success or failure. Risks in companies can find expression in many different ways (e.g., risks of fire, industrial injuries, product responsibility, industrial espionage and environmental disasters). However, the two crucial problems that usually arise when dealing with risks are the following:

(i) To what extent can they be considered the maximum acceptable level?

(ii) To what degree should these risks, considered acceptable, be further reduced and how should a reduction be balanced against costs and societal constraints?

For companies, many environmental risks can also be associated with unexpected events, like industrial accidents, or with routine events such as permitted emissions to air and water bodies. Some of these more generalised environmental risks are:

- Injurious effects suffered by persons as a result of exposure due to activities of a company, which can be expressed either as an individual risk and/or a societal risk.
- Non-compliance with regulations, which can result in substantial penalties and fines. (Any emission, legal or not, can generate future liabilities.)
- Loss of reputation, business and market shares, if an environmental disaster occurs in the company.

To handle these problems, various models for risk management have been developed. A very simple and general definition of risk management, as implied earlier, is *calculating combined risks and impacts and making decisions.* However, risk management applies to a very wide range of different situations, and it is necessary to describe the context of a risk analysis in a very comprehensive way, including the objectives of the analysis, the framework and goals. The general process of risk management can be subdivided in three main phases as below:

(i) **Risk analysis (or identification):** This involves the identification of hazards to people and the environment, the determination of the probability of these hazards happening and assessment of the seriousness of possible events.

(ii) **Risk assessment:** This means defining the limits or acceptability of the risk, which can be classified as acceptable or in need of reduction. Its main purpose is to define the company's reference safety policy. This policy, based upon the risk assessment, should include risk characterisation schemes, acceptable levels of risk, safety schemes, safety goals, safety standards and regulations. The risk limits for different activities of the company are set using a three-band index, consisting of:

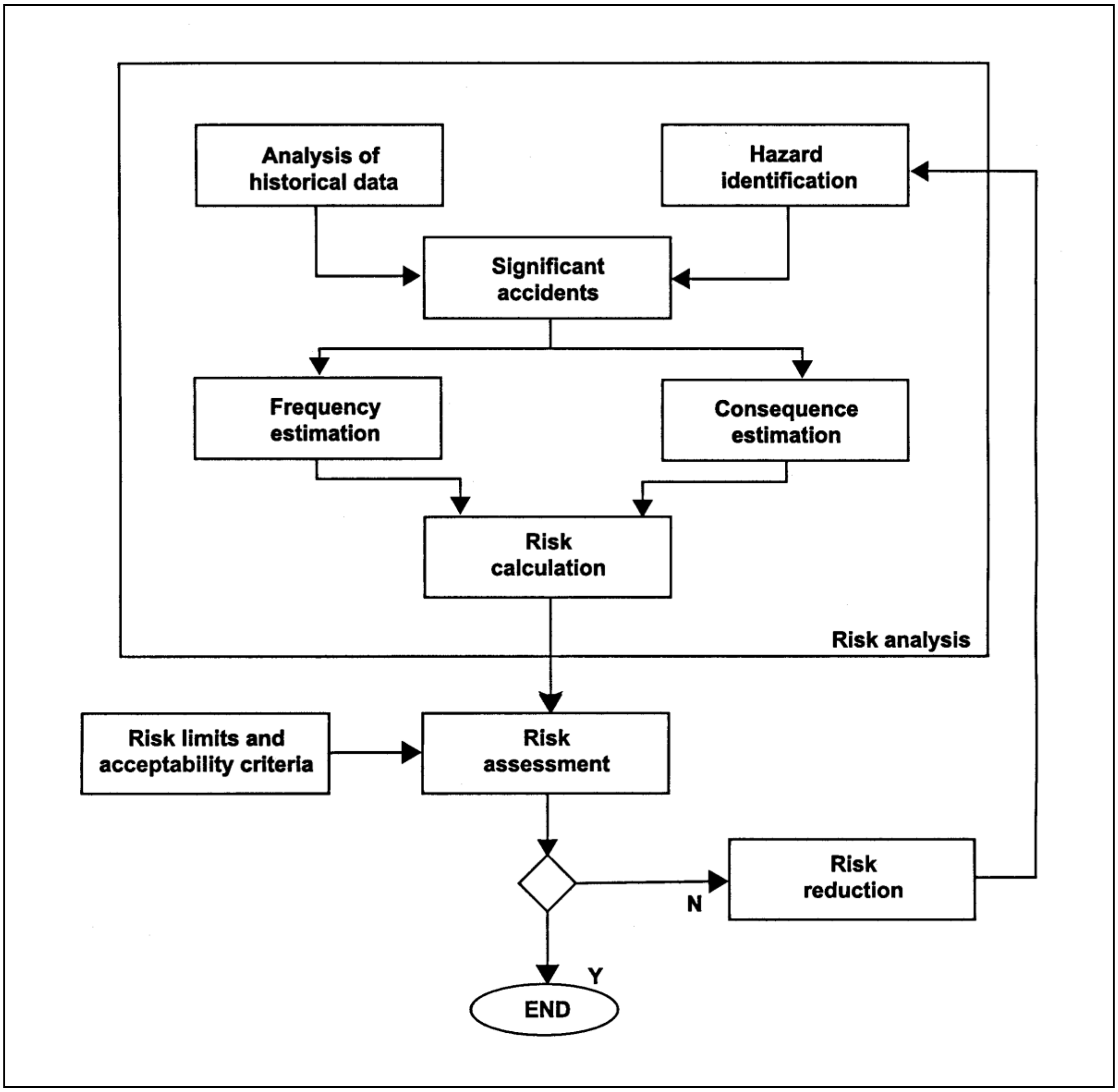
- the maximum acceptable risk limit should never be exceeded,
- the negligible risk limit, indicating the level below which it is not economically or environmentally sensible to try to reduce the risk,
- the gray area between the above risks, within which a trade-off must be made between cost effectiveness of risk reduction and the goal of achieving an acceptable level of risk.

The setting of risk limits in companies is a management procedure. But, it may also be a political choice for a municipality or even a parliament, depending on the consequences of an unexpected event (e.g., the risk of setting up a nuclear power plant).

(iii) **Risk control:** This involves the design and implementation of risk reducing measures and controls. This process includes various actions to be taken to achieve optimal allocation of a company's resources for risk control and reduction. The risk control analysis includes identification of measures to reduce risks, estimation of likely reductions to be achieved by various measures and estimates of the costs of the measures. Possible risk control measures should be ranked and listed to assist in further decision-making. Risk control in a company can be achieved by measures affecting the layout of different production facilities or procedures, application of additional safety devices, and, of course, the choice of less hazardous activities. Further risk reductions may be creating and maintaining safety areas around specific plants or devices.

To complete the risk control analysis, there are some useful tools that can be used such as multi-criteria decision analysis, cost-benefit analysis, sensitivity analysis and cost effectiveness analysis. The best available method for incorporating uncertainties should be used. During the risk control phase, companies should also prepare detailed emergency procedures with the public, and the responsible authorities should be informed. A well-structured plan will play an important role in limiting the effects on people's health and the environment. Figure 8.5 below shows the general procedure for risk assessment:

Figure 8.5
A General Procedure for Risk Assessment



LEARNING ACTIVITY 8.4

State 3 probabilities you would consider in risk analysis of a petroleum product storage tank in a refinery.

Note:
a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.

8.7.2 Ecosystem approach to risk assessment

Ecological assessment is the determination of harmful impacts at the population, community, or ecosystem level and may entail field studies, laboratory studies, or both. Measuring or accurately predicting a significant change in an ecosystem may require years or decades of study, yet the risk assessor and risk manager are faced with much more compressed timelines. For example, it is difficult to isolate easily studied areas of the wetlands from the surrounding ecosystem that supports it, which may require the risk assessor to include caveats and large uncertainties in the risk assessment.

Given this situation, most ecological assessments have focused on measuring structural components of the ecosystem, including the size and make-up of the habitat, biomass and standing crop of important plants and animals, the abundance and diversity of plants and animals and other measures.

Functional assessment

Functional measurements are useful for understanding the ecological health and sustainability of wetlands. These include hydrologic flux and storage, biological productivity, biogeochemical cycling and storage, decomposition and wildlife habitat. A functional assessment is based on the concept that variables (functions) that integrate key ecosystems-level wetland processes can be used as metric to compare impacts and quantify functional loss when compared to reference wetlands of the same hydro geomorphic classification (Brinson, 1993b; Richardson, 1994). Functional assessment can be a powerful tool for evaluating eco-system level impacts and risks within a timeframe necessary for risk assessment.

One of the main strengths of this approach is that it causes the risk assessor and risk manager to identify and resolve problems in the context of what a wetland does on the landscape. Although human values may ultimately drive the risk assessment, the inseparable linkage of values to ecological functions, particularly for constructed wetlands, becomes evident as this approach is planned and implemented. Moreover, it provides the risk manager with information on the functions that must be maintained or restored in order to provide the desired outcome.

Risk estimation

This refers to the estimation of the potential impact or the outcome or consequence of an exposure on a receptor (target) is estimated. In the case of accidental and sudden releases, the assessor will proceed to risk estimation, if the hazard assessment indicates a potentially significant probability or frequency of occurrence of an event and/or a consequence. The types of damage caused by sudden releases include acute toxic effects through dermal contact and inhalation of fumes, burns from fires and explosions and damage to humans, the built environment (e.g., flash floods due to dam failure), etc.

Chronic health effects are, however, unlikely to result from single, brief exposure to accidental releases. Chronic health effects on humans caused by exposure to low level releases of chemicals during day-to-day operations have generally been the focus of risk estimation in the context of EIA. Chemicals can exhibit a wide variety of chronic health effects in humans such as:

- sensitisation (e.g., the induction of dermatitis following regular skin contact with a chemical);
- neurotoxicity, or damage to the central nervous system, causing behavioural changes, tremors, etc.;
- teratogenicity, or damage to the embryo and foetus, leading to birth defects;
- mutagenicity, or damage that results in changes to the DNA structure in genes;
- carcinogenicity, or the development of malignant tumors and neoplasm (i.e., new growth).

The dose-response relationship is fundamental to the interpretation of toxic effects, i.e., there is a direct relationship between the exposure intakes, the duration of intake and the severity of the toxic effect. The basic quantitative difference in risk assessment for carcinogens versus that for non-carcinogens centres on the concept of thresholds. While non-carcinogens have threshold doses below which they fail to induce any discernible adverse health effects, carcinogens are often assumed to have no such effects, and carcinogenic risk is dependent on total dose, independent of whether the dose occurs over a short or long time period.

Because carcinogens tend to dominate public health risk when they are present, it is important to differentiate between chemicals that induce cancer and those that do not. Carcinogens can be grouped into two categories: genotoxic (i.e., carcinogens that operate through an initial effect on DNA or chromosomes that initiates cancer) and non-genotoxic (i.e., carcinogens that operate through chronic cell damage). The health risk to individuals is estimated separately for carcinogens and non-carcinogens. For non-genotoxic carcinogens and non-carcinogens, the ratio of the calculated intake to the relevant accepted daily intake (ADI) or tolerable daily intake (TDI): this ratio is estimated using the hazard index (HI).

For genotoxic carcinogens, the US EPA has applied a modelling technique to estimate the largest possible linear slope to extrapolate from high doses typical of experimental studies to the much lower doses typical of environmental exposures. A carcinogenic potency factor, called the potency factor, is computed from the data, which when multiplied by the calculated intake of the carcinogen, produces an estimate of the additional or incremental cancer risk to the individual as a result of exposure via the various exposure pathways. The risk is expressed as an estimated annual or lifetime risk of the chance of developing cancer (e.g., 1 in 1 million or 1×10^{-6}).

Table 8.3 gives some examples of impacts amenable to risk assessment:

Table 8.3
Impacts Amenable to Evaluation by Risk Assessment

Type of project	Project examples	Types of impact amenable to risk assessment
Extractive industry	Mines, quarries, cement manufacture	Damage to vegetation due to dust emission; effluent discharge; transportation risk; potential for flooding; health risks, associated with stack emissions
Waste management	Landfills, incinerators, chemical treatment plants, sewage treatment works	Health risk associated with stack emissions to atmosphere and release of leachate to groundwater; fire and explosive risk from landfill gas; accidental releases due to equipment failure, spillages or operational errors; transportation risk
Transport and infrastructure	Roads, railways, airports, harbours, dams	Structural failure; flood damage; transportation risk and accidents to road users; airborne accidents; quayside accidents
Chemicals, manufacturing, textiles, pulp and paper	Petrochemical plants, chemical and pharmaceutical production, dyeing works, paper and textile manufacture	Effluent discharge; ecological impacts in receiving waters; equipment failure; accidental chemical releases; fire and explosion risks
Forestry and agriculture	Afforestation, drainage and flood defence works, fish farming, livestock-rearing installations	Ecological and habitat changes; water and effluent management

Section 8.8 will introduce you to another essential tool called Rapid Urban Environmental Assessment.

8.8 RAPID URBAN ENVIRONMENTAL ASSESSMENT

Little information is readily available on environmental conditions, the interaction between urban development and ecosystems, or the managerial setting that exists to respond to environmental problems in the cities of the developing world. Recent attempts to develop such information have been incomplete because they:

- focused on a limited number of variables that do not present a complete picture of key environmental issues;
- took a narrow perspective by examining only one sector within the city;
- required several years of intensive, multidisciplinary research and analysis;
- did not develop a set of urban environmental data.

As a methodology, rapid urban environmental assessment (RUEA) draws its inspiration from rapid rural appraisal and participatory rural appraisal. However, urban assessment is much less anthropological and community-focused than its rural counterparts primarily because cities involve much larger populations and spatial areas.

Description of methodology

The RUEA methodology consists of a three-step process as under:

(i) **Measurement:** This involves data collection through an urban environmental data questionnaire.

(ii) **Observation:** This involves preparation of an urban environmental profile, using data from the questionnaire and research assistance from local investigators.

(iii) **Validation and action:** This involves discussion of the results through a series of consultations, culminating in a priority-focused workshop.

This three-step process is adopted to enable local experts and citizens to rapidly assess the state of the urban environment.

Users of the tool

Local governments of urban or urbanising localities use RUEA, as it provides a comprehensive diagnostic approach to the determination of a wide range of environmental problems and solutions. Local planning bodies may particularly steer its implementation.

Application/scope

The process of RUEA (i.e., data collection, profile and consultations) can provide an informational and consensual basis for preparing an urban environmental management strategy with a view to accelerating the improvement of environmental conditions in cities, especially by integrating key aspects of urban policy and environmental management.

The urban environmental management strategy builds on existing sector and project work but emphasises continuity in decision-making to implement agreed policies and approaches. It should provide a decision-making framework for private investments (for public) while recognising that the investments will be primarily private (by households and firms). It, therefore, requires a participatory process among decision-makers in government and the private sector, often using working groups of officials in consultation with technical specialists and key private and informal sector actors, as they agree and commit themselves to act on the policies and strategies they themselves will define.

This strategy can be developed in a number of different ways but should generally include consideration of health effects and environmental damages (i.e., costs), comparison of alternative long-term strategies to achieve environmental quality goals at the lowest economic cost to the urban region, identification of appropriate policies and instruments to implement the least cost strategy and an assessment of its institutional and financial feasibility.

In Section 8.9, we will introduce you to a relatively new concept called eco-mapping. This is extremely useful for small and medium enterprises (SMEs) to manage their activities.

8.9 ECO-MAPPING

Environmental management standards such as ISO 14001, or the EMAS regulation, which are becoming prevalent throughout the world at the moment, threaten the very existence of SMEs.

Several million micro-enterprises and SMEs in many parts of the world grapple with the problems of managing the environmental impact of their activities due to, among others, inadequate tools and resources (http://www.inem.org/htdocs/inem_tools.html). The greatest problem they face, however, is one of awareness and changing behaviour. Nevertheless, they will soon be required to show customers, public administrations, non-governmental organisations, insurance companies, neighbours and professional associations that they have implemented environmental management.

What is eco-mapping (or eco-maps)?

Eco-mapping is a visual and easy-to-use tool which enables employees to get involved in environmental management in a company. The results of a quick and visual environmental review can be equivalent to that of expensive scientific studies conducted by consultants. If the results of a scientific study can be compared to a high-resolution image, those of eco-maps, which do not cost anything, can be compared to the Polaroid photograph of environmental management. Both will enable you to take positive action.

Eco-mapping is a road map of a site, a shop floor, a workshop, etc., which can lead to improved environmental management and which can provide a solid basis for a more formal environmental management system according to ISO or EMAS. In essence, it is

- an inventory of practices and problems;
- a systematic method of conducting an on-site environmental review;
- a collection of information which shows the current situation using pictures;
- a work and awareness-raising tool;
- a do-it-yourself tool for SMEs;
- a tool which allows employee involvement and participation.

Eco-maps can be used to determine:

- a site in its urban environmental context;
- consumption of water and discharge of waste water;
- storage of flammable, dangerous or hazardous substances in relation to groundwater;

- emission of air pollutants and dust, odour and noise;
- consumption of energy.

How to use eco-maps?

The materials needed are A4-sized papers and a photocopy machine. Eco-mapping is done at end of the accounting year. It is updated once a year, or when the site is renovated or the activities are extended. From small manufacturing and service companies to large structures and local authorities can use the maps. Eco-mapping involves:

- **Mapping of the urban situation:** Make a map of the site including car parks, access areas, roads and the surrounding environment. The map should reflect the real situation.
- **Mapping of the site:** Draw the outline of the site using a scale and showing the interior spaces. This map should be copied and will be the basis for the work to be done. The maps should show the real situation and should be simple, recognisable and in proportion. They should have a date, a name and a reference. Certain objects such as machines, boilers, etc., will have to be in order to orient you straight away. If a site covers very different areas, mapping can be done for different areas separately and then merged.
- **Developing symbols:** Symbols can be developed by using either hatched lines when the problem to be studied is small or circle if the problem is large. The more serious the problem the thicker the circle.

In order to improve the quality of the eco-maps, standardised pictograms can also be used.

So far, we discussed some of the environmental management techniques with particular reference to urban contexts. They are useful in environmental management. But, for strategic reasons, environmental education is imperative. We will discuss this aspect of environmental management, next.

8.10 ENVIRONMENTAL EDUCATION

Environmental education is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action (UNESCO, Tbilisi Declaration, 1978) (http://www.epa.gov/enviroed/epagoals.html). It does not advocate a particular viewpoint or course of action.

The components of environmental education are:

- awareness and sensitivity to the environment and environmental challenges;
- knowledge and understanding of the environment and environmental challenges;
- attitudes of concern for the environment and motivation to improve or maintain environmental quality;
- skills to identify and help resolve environmental challenges;
- participation in activities that lead to the resolution of environmental challenges (UNESCO, 1978).

Environmental education is essential for improving the quality of our lives. Let us now discuss this aspect.

Protecting human health

The link between environmental challenges and human health is clear. Lead poisoning from paint and pipes, air pollution, pesticides in water and food supplies, increased threats of skin cancer from depletion of the ozone layer and other environmental and health issues are a veritable cause for public concern. Environmental education can help prevent or mitigate environmental human health problems by providing the public with information on the causes of environmental pollution, how pollutants may affect health, how to assess real versus exaggerated risks and how to make informed and responsible decisions that prevent or mitigate the effects of pollution on health.

Advancing quality education

Educators and public officials generally believe that improvements are needed in the nation's public education system to enhance student learning. Many educational scholars and practitioners agree that students are not doing well at thinking, reasoning, analysing or problem solving. Many goals of education reformation emphasise the need to strengthen core subjects, improve critical-thinking and problem-solving skills and relate learning in the classroom to the needs and issues of the community.

Environmental education has a tremendous potential to contribute to these goals of education reform. For example, it can strengthen teaching in many core subjects, especially science, because science is the basis for solving many of our environmental challenges. At the same time, environmental education can promote interdisciplinary teaching because environmental topics can be addressed from many different perspectives, including scientific, historical and cultural.

Environmental education can also bring local environmental challenges into the classroom to improve analysis and problem-solving skills.

Creating jobs in the environmental field

Protecting the environment creates new jobs. Employment opportunities in the environmental field cover the spectrum of careers from manual labour to high technology and management. For example, there is an increasing demand for individuals with specialised scientific and technical skills to develop more effective pollution prevention and control technologies in areas such as air pollution control, environmental energy sources, hazardous waste management, resource recovery and instrument manufacturing. Environmental education and training can help ensure an adequate supply of well-trained environmental personnel to deal with the nation's increasingly complex environmental challenges. Environmental education's emphasis on critical-thinking and problem-solving skills equips learners in dealing with rapidly changing technologies in the workplace.

Promoting environmental protection along with economic development

Our future depends on the ability to use the natural resources in a sustainable manner. Sustainable development poses two fundamental educational challenges. One is to promote informed decisions that are conducive to sustainability and the other is to teach the benefits of integrating conservation with the need for economic development. Environmental education contributes to sustainable development efforts by demonstrating ways to promote informed decision-making and teach the benefits of linking conservation and economic development. Environmental education research has identified key strategies for developing education programmes that lead to responsible decision-making, and practitioners have developed programme models for incorporating a range of perspectives into the resolution of issues. These educational tools and strategies can be applied to efforts to ensure sustainable development.

Encouraging stewardship of natural resources

Interest in protecting a nation's natural resources, including species and their habitats, arises from the respect most people hold for the nation's past and a belief in its future. This interest also stems from a strong desire to protect and enjoy nature and to pass it on to our children. There is a need to increase the understanding that the health of individual species can be strong indicators of the health of the entire environment and that biological diversity has ecological and economic importance. Environmental education enhances the understanding of the public about the need for healthy plant and animal life and biodiversity. It also educates the public about the impact of their actions on natural ecosystems and how positive steps taken to minimise impacts on these ecosystems will translate into improvements in our overall environment.

SUMMARY

Following our discussion of the major environmental management (EM) tools in Units 4 to 7, in this Unit, we dealt with some of the other EM techniques with particular reference to urban contexts. We began the Unit by discussing environmental monitoring. We then explained the use of mathematical modelling to deal with environmental issues, and in that context, introduced forecasting and growth modelling. We also discussed sensitivity analysis and geographical information system. The other techniques we discussed in the Unit are environmental profile, environmental technology and risk assessments, RUEA and eco-mapping. We closed the Unit by bringing to the fore the importance of environmental education.

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Lecture 8

Model Answers to Learning Activities

LEARNING ACTIVITY 8.1

Input parameters: Noise level at source, distance of receptor from source.
System parameters: Temperature, humidity.
Output parameter: Noise level at receptor.

LEARNING ACTIVITY 8.2

We know:

$$r = \left(\frac{R_0}{1-\left(N_0/K\right)}\right) = \frac{0.017}{1-(5.0*10^9)/(15.0*10^9)} = 0.0255$$

The time required to reach 7.5 billion, half of the final population size, can be found as:

$$t^* = \frac{1}{r}\ln\left(\frac{K}{N_0}-1\right)$$

$$= \frac{1}{0.0255}\ln\left(\frac{15*10^9}{5*10^9}\right)-1) = 27yrs$$

To determine the number of years that it will take to reach 14.0 billion, we need to solve the equation for *t*:

$$N = \frac{K}{(1+e^{-r(t-t^*)})}$$

$$T = t^* - \frac{1}{r}\ln\left(\frac{K}{N}-1\right)$$

$$= 27 - \frac{1}{0.0255}\ln\left(\frac{15}{14}-1\right) = 130yrs$$

LEARNING ACTIVITY 8.3

The parameters for sensitivity analysis in prediction of impacts of combustion of coal in thermal power plant on surrounding air quality are:

- Ash content in coal.
- Sulphur content in coal.
- Stack height.
- Frequency of wind direction towards sensitive receptors.

LEARNING ACTIVITY 8.4

The probabilities that need to be considered in risk analysis of petroleum product storage tank in a refinery are:

- Rupture.
- Leakage.
- Explosion.