CHAPTER NINE

Sustainability, Environmental and Social Considerations

This chapter explains how sustainability, environmental and social considerations inform the planning and design of engineering projects. The concept of sustainability and its assessment can be challenging. However, it can also be effectively used as a basis for the assessment of development and community projects. The concepts presented in this chapter allow for community values to be incorporated into decision making processes by placing an emphasis on the environmental and social implications of engineering projects. Methods for taking account of sustainability, social and environmental issues are briefly presented.

9.1 INTRODUCTION

Prior to the 1970s, engineering projects were often human-centric. Engineers focussed primarily on the technical and economic aspects of projects, without giving much concern to the social and environmental impacts of their work. To a large extent this was a reflection of the priorities of society at the time, and to a lesser extent, due to an insufficient understanding of the interconnectedness between engineering works and natural and social systems. Engineers now recognise that they play a critical role in the wise use, conservation and management of resources. They also recognise that they have an obligation to ensure that the needs of future generations are considered. This is reflected by professional bodies through accreditation requirements for engineering programs, and through codes of ethics for practising engineers.

In 1828 Thomas Tredgold of the Institute of Civil Engineers described engineering as the art of directing the great forces of nature for the use and convenience of man. As we have seen already in Chapter 1, nature tended to be regarded as a powerful adversary to be tamed. Today such views are tempered by the realisation that the world has finite resources and the emphasis now is on the wise use of resources, not only to protect and conserve the environment, but also to achieve a sustainable way of life into the foreseeable future.

The concept of sustainable development has been discussed extensively in past decades, with the mainstream definition being that of the Brundtland Commission of 1987 (WCED, 1987):

> *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

This concept has developed further, and engineering systems, policies, designs and plans can be considered and evaluated today within sustainability frameworks.

In Section 9.2 of this chapter, we look at the concept of sustainability and in Section 9.3 at the techniques which are used by engineers in planning and design to deal effectively with sustainability as an over-riding goal of engineering work. While environmental and social issues are clearly inter-related with considerations of sustainability, they are dealt with separately in this chapter. Environmental considerations and assessment programs are introduced in Sections 9.4 and 9.5, while social issues and assessment tools are dealt with in Sections 9.6 and 9.7.

9.2 SUSTAINABILITY

The systems approach provides a simple and consistent basis for investigating sustainability at all levels of society, from the global scale down to the individual. Gilman (1992) used systems concepts to provide the following definition of sustainability:

> *The ability of a society, ecosystem, or any such ongoing system to continue functioning into the indefinite future without being forced into decline through exhaustion or overloading of key resources on which the system depends.*

Based on this definition, Foley et al. (2003) have shown that to achieve sustainability it is necessary to manage appropriately all the resources that a system relies on. These include the natural, the financial, the social and the man-made infrastructure resources that are important to the functioning of the system.

Roberts (1990) has shown that self-sustaining systems in nature are generally closed-loop systems that evolved gradually over time. In the past when humans developed production systems, they have relied on an open loop, once-through use of resources, which results in much waste. To be sustainable, it is necessary to use closed-loop systems. This emphasis on a closed loop for sustainable outcomes can also be seen in discussions related to a *circular economy*. The objective of a circular economy is to maximise value at each point of a product's life (Stahel, 2016). Another closed-loop system concept is the *cradle to cradle* approach. This approach is in contrast to the linear *cradle to grave* approach. The cradle to cradle approach recognises that the perceived end of life for a given product can, and should, become the start of another product life and therefore an interconnection is introduced between product life cycles. A cradle to grave approach also recognises the product life cycles, but often includes waste at the end of the product life. Figure 9.1 shows a conceptual model of the initial extraction or use of resources, followed by the processing, transportation and consumption of the modified resources as a closed-loop system that can evolve over time. More complex models include interconnected systems and cradle to cradle connections between product life cycles.

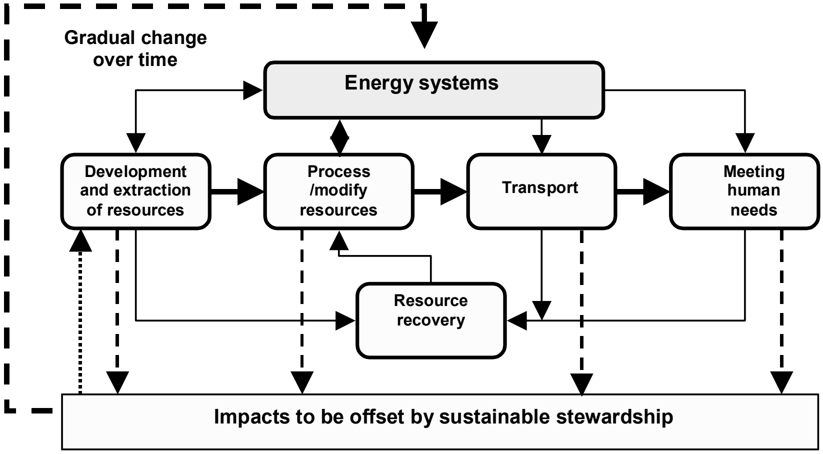

Figure 9.1 Closed-loop system representation (adapted from Roberts, 1990).

A key element of the model is the stewardship of the natural environment that is needed in order to provide a balance to the processes of extraction, modification and transportation. The main element of this closed-loop system is the recycling of waste from manufacture and consumption within a continuous loop. Energy inputs are a crucial element in the closed-loop system. For many natural systems the sun is the natural source of energy, but this is not so for man-made systems.

A conceptual model that can be used to assess the sustainability of a system or of sustainable system development (Foley et al., 2003) is shown in Figure 9.2. It outlines the flow of resources within the system. The model identifies infrastructure and other human-made resources (I) as a key element of sustainability. Infrastructure for urban development includes buildings, and the water supply system, as well as systems for waste, transport and energy. Such a systems approach provides a good platform for assessing development and sustainability, where infrastructure and resource flow are principal considerations.

Each subsystem within the larger development system can be modelled (e.g. a single house within a city development). The flow of resources such as water, energy and finance to and from the system can also be included in a more holistic way than in many other currently available tools.

A systems approach to the assessment of sustainability is not new. It was applied in early computer modelling studies in the 1970s (e.g. Meadows, et al., 1972) and in more quantitative studies which have continued up to the present. A major conclusion from such systems modelling, suggested by Suter (1999), is “that humankind needs to re-evaluate its exploitative attitude towards humans and the earth itself”.

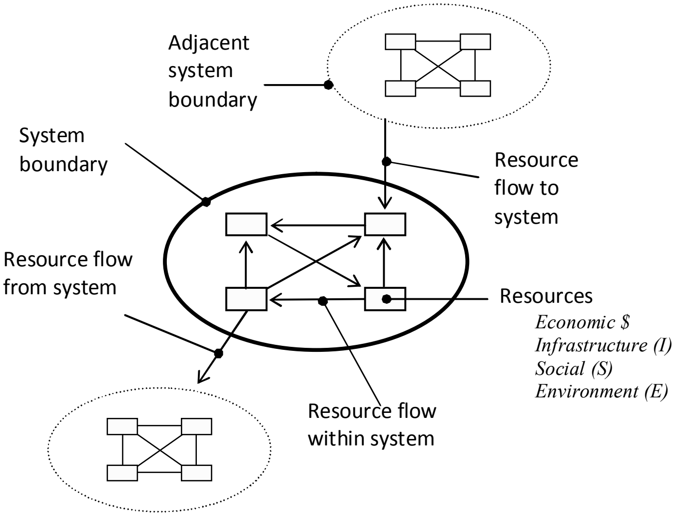

Figure 9.2 System representation (adapted from Foley et al., 2003).

Another application of the term sustainability relates to corporate social responsibility. This can impact engineers and their work through both the strategic direction and the investment decisions of the organisations within which they are employed or interact. Sustainability has been adopted in the business world to connote the principles of social and environmental responsibility. Increasingly business organisations have recognized that profits alone do not guarantee continuity of existence for their companies and that sustainability adds to their long-term business viability. Investors also see sustainability issues, such as controlling greenhouse gases, as priority concerns to be addressed by management. Since the late 1990s, the Global Reporting Initiative (www.globalreporting.org) has set the benchmark for sustainability reporting at the corporate level and the Dow Jones Sustainability Index (www.sustainability-indices.com) has become a mainstream investment consideration.

The final application of the term sustainability, as discussed here, relates to considerations of natural capital. Schmidheiny (1992) of the World Business Council on Sustainable Development suggested that population growth and economic development will eventually be constrained by environmental and social pressures. The question of what level of population is sustainable for the world is the focus of much debate amongst many scientific researchers and has been since the time of Thomas Malthus in the late 1700s. The key to the answer is in maintenance of natural capital and the level of resource use which is required for a standard of living that can be perpetuated for future generations. Sustainability has thus been explained as being the state for which all social well-being and development are within the Earth's biological capacity (Wackernagel and Rees, 1997).

Club of Rome

The Club of Rome was founded in 1968 and has been described as "a think tank and a centre of research and action, of innovation and initiative". It is composed of a group of scientists, economists, business people, senior public servants, heads of state and former heads of state from around the globe and addresses questions confronting the global society. The term "problematique" was developed by club members for the inter-related issues that were to be examined. The Club of Rome commissioned the book "Limits to Growth" which was published in 1972. Twelve million copies of the book were sold worldwide, in 37 languages. The book challenged a basic assumption of economic theory that the resources of planet Earth could be infinite. The book was based on computer modelling of the consequences of the growth of global population. Various scenarios researched pointed to a major economic crisis occurring in the early 1990s. This did not happen. Subsequent updates on the book have been undertaken and in retrospect, one needs to ask, was "Limits to Growth" a fair or a false warning?

Adapted from Suter (1999)

9.3 PLANNING AND DESIGN FOR SUSTAINABILITY

Time is a key consideration for sustainability as systems evolve and communities develop. This was highlighted by Fleming (1999) who has suggested that sustainability needs to be considered within cycles of continuous improvement. In evaluating the sustainability of engineering systems, projects, processes and operations, a key aspect to consider is the stream of resource usage. Various tools can assist in such evaluations, and are dependent on the level of society to which they are being applied. Examples of readily available tools available on the Internet are listed in Table 9.1. Some are produced by non-government organisations, some represent formal government reporting and others are project specific or proprietary tools.

The continuous improvement methods employed by industry, such as cleaner production and total quality management, evaluate the level of goal achievement over time. Many of these approaches use a systems approach to examine resources so that there is minimal waste with the conversion of linear, once-through systems, to closed-loop systems that reduce waste. These are mainly improvement processes used by industry to become more sustainable at a particular industry level, as well as processes used by governments to align with agreed global initiatives and principles. In 1992, the first set of guiding principles emphasizing sustainable development, Agenda 21, were agreed to at the Earth Summit in Rio de Janeiro. In 2000, eight Millennium Development Goals were declared, and in 2015 countries adopted 17 Sustainable Development Goals. These principles and goals are not an assessment of sustainability in their own right. They inform assessments and provide direction.

Table 9.1 Sustainability reporting, improvement processes, tools and metrics

National/regional/community level

- Genuine Progress Indicator
- Living planet report
- Compass index of sustainability
- Human Development Report and Index
- Measuring Australia's progress

Corporate

- Global Reporting Initiative
- Environmental management systems (ISO 14000)
- Sustainable, responsible and impact investing
- Triple bottom line
- Social responsibility (ISO 26000)

Industry / Project / Product / Process

- Cleaner production
- Zero emissions
- Environmental impact assessment
- Factor 4
- Factor 10
- Ecological/water footprints
- Sustainability
- LEED® building rating system
- Total quality management
- Life cycle assessment (ISO 14040)
- Eco-labelling
- Green procurement
- Natural capital
- Water sensitive urban design
- Green star building assessment
- Arup's Sustainable Project Appraisal Routine (SPeAR®)

UN Sustainable Development Goals

The UN Sustainable Development Goals are part of a broader sustainable development agenda, agreed upon by supporting countries in September 2015. The goals are

1. no poverty
2. zero hunger
3. good health and well-being
4. quality education
5. gender equality
6. clean water and sanitation
7. affordable and clean energy
8. decent work and economic growth
9. industry, innovation and infrastructure
10. reduced inequalities
11. sustainable cities and communities
12. responsible consumption and production
13. climate action
14. life below water
15. life on land
16. peace, justice and strong institutions
17. partnerships for the goals

Each of the goals has supporting facts and figures, and importantly targets for the year 2030.

http://www.un.org/sustainabledevelopment/

In many governments and organizations, a set of sustainability criteria are used to assess the relative merits of projects, processes and products. Included within these assessments is often interaction with the stakeholders and community groups through participatory and consultation programmes.

A major push for reduction of the use of resources comes in programmes such as Factor 10, which has the goal to lower the use of natural resources for generating material wealth, using new technology, by an average factor of ten within 30 to 50 years for the purpose of approaching sustainability. This is equivalent to increasing resource productivity tenfold over the same time period (Schmidt-Bleek, 1993). Sustainability assessment requires the development of a clear set of criteria against which the assessment can be conducted. This includes considerations of environmental, economic and social factors. The Triple Bottom Line (TBL) approach establishes individual indicators to show how well a company satisfies goals in each of these three areas. Usually for TBL reporting indicators are chosen for a number of criteria for each factor and then presented using a set of bars of different colours or stars to indicate how well a company is doing against particular criteria. The establishment of principles-based criteria for assessment of sustainability can improve the standard TBL approach.

A framework for assessing the natural capital within a region or within an organization can be developed with the use of systems such as the "Compass index of sustainability" to stress the *inter-connected* nature of the elements of environment, economics, and social well-being (AtKisson and Hatcher, 2001; Hargroves and Smith, 2005). Over time, the results of the planning and engineering of cities are measured by such indicators. Predictions of changes to the development of the city infrastructure and the resource input and output for a city's existence can also be made against these criteria. The design of individual buildings involves choices of materials to be used, lighting, air conditioning and water use. Each of these choices for achieving sustainability goals will involve assessment of embodied energy within materials used, energy use over the life of products, the ability of the product to be recycled and satisfaction of performance criteria.

Sustainability assessment does not replace Environmental Impact Assessments or functional decision making based on Life Cycle Analysis or Social Impact Analyses or combinations thereof. A sustainable assessment tool needs to be incorporated within the decision-making framework to ensure that decisions in planning are, in fact, sustainable (Pope et al., 2004). Sustainability assessment can and should be applied to evaluating proposed and existing processes and projects at all levels of governmental and project decision making. Incorporating sustainability through the design and implementation phases of a development could involve the integration of social and environmental effects of a longer time horizon into analyses by the proponents of projects. Sustainability assessment requires defining clear societal goals (e.g. the Sustainable Development Goals) which can be translated into criteria, against which assessment is conducted. It is essential that the assessment method is able to discern sustainable outcomes from unsustainable ones.

Ecological Footprint

Ecological Footprint (EF) is a measure of humanity's dependence on natural resources. For a certain population or activity, the EF measures the amount of productive land and water required to sustain the current level of resource usage for the production of goods and services and the assimilation of waste required by that population or activity.

In 2001, the world average EF was 2.55 global hectares per person, >30% above the current global capacity (Venetoulis and Talberth, 2005). The lifestyle of the average global citizen can therefore be considered as unsustainable. Natural resources are being used faster than they can be regenerated.

The size of an EF can change over time, depending on population, consumption levels, technology and resource use. EFs are measured in global area (hectares or acres). Wackernagel et al. (1997) defined biologically productive areas as (a) arable land; (b) pasture; (c) forest; (d) sea space (used by marine life); (e) built-up land; and (f) fossil energy land (land reserved for carbon dioxide absorption). The current global biologically productive area is 10.8 billion hectares, of which 21% is productive ocean and 79% is productive land. This represents less than one-quarter of the Earth's surface.

An individual's resource consumption is not restricted to local resources. The resources used by an individual are from around the world, clothes from China, cars from Korea and food from many different places. From a comparison of the Ecological Footprint to the existing biologically productive area, the sustainability of an activity, lifestyle or population can be determined.

An ecological footprint of Greater London, prepared by Best Foot Forward Ltd. (http://www.citylimitslondon.com/) found that London's EF was 42 times the current capacity, or 293 times the size of London. This equated to 49 million global hectares, twice the size of the UK, and roughly the same size as Spain. Is this sustainable?

Australia has a usage of 7.0 global hectares per person, making it the 5th highest in the world. There are many websites that enable calculation of your individual footprint on the earth (http://www.footprintnetwork.org/), and to compare it with different countries.

The Matrix Evaluation of Sustainability Achievement is one such method (Fleming and Daniell, 1995; UNEP, 2002) which uses a weighting technique against a set of sustainability criteria and combines them with fuzzy set analysis. The important step is the definition of specific criteria which can be obtained to achieve the overall project goal. In the case of a building, this might be to achieve a reduction of 50% of projected CO_2 emissions over an existing conventional design. Therefore, the inclusion of sustainability as a project goal could totally change the final solution from that resulting from a short-term economic goal.

Global Reporting Initiative

The Global Reporting Initiative (GRI) provides a reporting framework for companies and organisations to guide the preparation of consistent and comparable sustainability reports. First released in 1997, the GRI has been progressively developing resources as awareness of, and expectations associated with, corporate sustainability reporting have increased. GRI gained legitimacy in 2002 when it became a collaborating centre with the United Nations Environment Program (UNEP). It is aligned with the International Standard *ISO 26000:2010, Guidance on social responsibility* and also now with the United Nations Sustainable Development Goals. The GRI G4 guidelines will be phased out in 2018 and replaced by a series of standards. These standards are modular and define disclosure requirements using the following structure:

- General Disclosures
- Management Approach
- Economic Standards
- Environmental Standards
- Social Standards

In addition, there is a Foundation Standard and Glossary as supporting material.

Global Reporting Initiative, (2016)

9.4 ENVIRONMENTAL CONSIDERATIONS

History of Environmental Concerns

While it is true that the environment and sustainability have become much more of a focus for concern among people since the 1970s, it would be quite wrong to think that prior to that time there were no problems and concerns. In ancient Greece some 2500 years ago, Plato lamented the consequences of excessive logging and grazing in the mountainous region of Attica, near Athens. Similar concerns were raised around 1000 years ago in Japan where excessive eroded granite built up in Lake Biwa, due to logging for the construction of a temple (Parker, 1999).

Environmental legislation also dates from ancient times. In Rome all wheeled vehicles were prohibited between sunrise and two hours before sunset to improve the situation for pedestrians. This law fell into disuse, and in the 3rd Century AD, writers complained about the level of noise pollution generated by traffic in the streets. The city of Florence had laws governing the polluting of the rivers Arno, Sieve, and Serchio as early as 1477 (Higgins and Venning, 2001) and in 1810 Napoleon was issuing decrees aimed at eliminating polluting industries from the centres of cities.

In Australia, some of the earliest laws dealt with environmental issues. There were laws to protect the quality of the stream which supplied water for the original settlement in Sydney and it was prohibited to fell trees within 50 feet (15 metres) of the stream. People were not allowed to throw rubbish into the stream or have pigsties within a prescribed distance. In 1839, just three years after the city of Adelaide was settled, the state of the Torrens River was so bad that laws were passed to prevent, among other things, people driving cattle through it. This was the city's only water supply and yet it was treated with scant regard by many. There are many countries today where this still happens but, as the world becomes more urbanised, there is a need to be aware of the impact of human activity on the state of the planet Earth.

The Tragedy of the Commons

The tragedy of the commons has played itself out worldwide at various times and to varying degrees. It can be explained as follows: when a group of herdsmen have access to a common pasture, it is in each individual's best interests to increase the size of their herd without reference to the overall carrying capacity of the land. However, this leads to the destruction of the common pasture, so that everyone loses. This type of situation occurs in many ways, such as when an increasing population results in increased waste disposal into the commons: rivers, lakes, oceans, and atmosphere.

A major issue in city development involves the concept of the commons in regard to the decreasing quality of air and water due to emissions from transport systems and runoff from road systems. Another issue linked to the commons on a global scale is the consumption of energy by the developed nations which has resulted in producing CO_2 emissions which have contributed to global warming. Those activities that are considered to be necessary for a high quality of life: food; energy and transport systems; communication systems; the supply of infrastructure; supply and maintenance of water and waste water systems; health systems; and the management of waste all need energy and hence generate CO_2 emissions. There is much discussion on the linkages between CO_2 production, climate change and quality of life. The linkage between the use of energy and the quality of life can be examined by inspection of emissions of CO_2 and energy use in industrialised countries in the world. The United Nations Human Development Index (HDI) is a measure of poverty, literacy, education, life expectancy, childbirth, and other factors for countries worldwide. It is a means of measuring well-being and has been used since 1993 by the United Nations Development Programme (UNDP, 2013). To compare the impacts of development across nations with respect to emissions, the Human Development Index (HDI) has been used in conjunction with CO_2 emissions per capita as given in Table 9.2.

Table 9.2 World CO_2 emissions (per capita).

HDI rank 2013	Country	Carbon dioxide emissions per capita (tonnes) 2008	Carbon dioxide emissions annual growth (%) 1970/2008
1	Norway	10.5	1.0
2	Australia	18.6	1.2
3	United States	18	-0.4
4	Netherlands	10.6	-0.1
5	Germany	9.6	-
6	New Zealand	7.8	1.1
7	Ireland	9.9	1.1
8	Sweden	5.3	-2.0
9	Switzerland	5.3	-0.6
10	Japan	9.5	0.7
101	China	5.3	4.7
136	India	1.5	3.8
153	Nigeria	0.6	1.4

Source: United Nations Development Program, 2013.

Energy Use

Energy use in developing nations is based on traditional systems of wood and coal, and not electricity. As these nations convert to electricity and develop industries that use more energy, there will be a major increase in CO_2 production across the globe. The growth in energy use of the developing nations is only just beginning and can be expected to increase twenty fold in the next 20–30 years. The need to develop better technologies for the sustainability of cities and lower CO_2 emissions are two goals which engineers need to address if there is to be equity among nations.

Of course the future cannot be predicted with certainty, but engineers will help create it. The goals that are now chosen for all development will dictate the future. In the past, individual goals were pursued independently of each other, leading to the present crises for social well-being, the environment and the economies of some countries. The need is to develop a balance between the use of resources, the environment, and social well-being to achieve sustainability into the future.

9.5 ENVIRONMENTAL ASSESSMENT PROGRAMS AND TECHNIQUES

Environmental Impact Assessment (EIA) is now an integral part of the planning of an engineering project, just as economic, financial and social issues and technical analyses are. A definition of EIA that looks at the consequences is as follows: "Environmental Impact Assessment is a tool designed to identify and predict the impact of a project on the bio-geophysical environment and on society's health and well-being, to interpret and communicate information about the impact, to analyse site and process alternatives and provide solutions to sift out, or abate/mitigate the negative consequences on man and the environment" (UNEP, 2003).

Numerous countries have implemented EIA regulations from the late 1960s onwards. The origin of EIA stems from the National Environmental Policy Act 1969 (US), from which the practice has spread around the world. The Environment Protection (Impact of Proposals) Act 1974 (Commonwealth of Australia) was the first dedicated EIA legislation in the world and has now been replaced by Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth of Australia). Within Australia there is also state legislation. For example, in Victoria the Environment Protection Act 1970 provides the legislative framework for environment protection in Victoria, but it is supplemented by other acts such as the Environmental Effects Act of 1978 for performing Environmental Effects Assessment.

EIA is thus the means of including environmental factors with both economic and technical considerations at the planning stage of a project. The process of EIA:

- identifies the potential environmental effects of undertaking a project;
- presents these environmental effects with the advantages and disadvantages of the proposed project to the decision makers; and
- forces stakeholders to consider the environmental effects and informs the public of the project while giving them the opportunity to comment on the proposed project.

EIAs are necessary for large projects and are required under relevant planning legislation. They are necessary for mining projects, new transport corridor projects, major infrastructure development, large industrial factories or expansion of existing facilities. The EIA is a means of highlighting potential environmental and ecological disturbances which would be more difficult and more expensive to correct after their occurrence than before. One major benefit of EIAs is the assessment of habitats of many rare species of flora and fauna which might never have been investigated had it not been for the requirement of the EIA.

In project planning, environmental issues are now addressed at all stages of the planning process, from conception to closure and rehabilitation. There are alternatives that can be considered at an early stage to counter adverse assessments, such as:

- abandoning a project or a process;
- proposing alternatives to projects which have extreme detrimental impacts on the environment; and
- proposing alternatives for projects not economically or financially viable.

Very few projects have been deemed not viable merely because of increased costs of environmental controls. For example, at a new paper pulp mill the additional cost has been assessed to be less than 3% of the initial investment (UNEP, 2003). The environmental controls that need to be put in place will vary from industry to industry, with significantly higher costs for some industries. Major research projects are being undertaken on the sequestering of carbon dioxide from energy production. A detailed assessment of the practices and methods involved in EIAs is contained in Canter and Sadler (1997) but the key elements of an EIA include:

- Scoping: identify key issues and concerns of interested parties;
- Screening: decide whether an EIA is required based on information collected;
- Identifying and evaluating alternatives: list alternative sites and techniques and the impacts of each;
- Forwarding measures that deal with risks and uncertainties of the proposed project and to minimise the potential adverse effects of the project; and
- Issuing a report called an environmental impact statement, which covers the findings of the EIA.

Environmental Impact Statements (EISs)

The EIA process produces a document, called the EIS, which provides information on the existing environment and predictions about the environmental effects which could flow from the proposal. Whether an EIS is to be done in its entirety or whether some other report is warranted by the proposal is decided by government legislation. In South Australia there is an independent statutory authority, the Major Developments Panel, which controls the level of reporting required: an Environmental Impact Statement which is required for the most complex proposals; or a Public Environmental Report which is required for a medium level of assessment, sometimes referred to as a “targeted EIS”; or a Development Report required for the least complex level of assessment.

The EIS is the document that reports the findings of the EIA and, depending on each country’s legislation, is now often required by law before a new project can proceed. A typical EIS has three parts with different levels of detail: an Executive Summary in a style that can be understood by the public; the main document containing relevant information regarding the project; and a volume containing the detailed assessment of significant environmental effects. If there are no significant effects either before or after mitigation, this volume will not be required. The EIS should

- describe the proposed action as well as alternatives;
- predict the nature and magnitude of the environmental effects;
- identify the relevant human concerns;
- list the impact indicators and determine the total environmental impact; and
- make recommendations for inspection procedures and alternatives to the plan.

As part of the EIA, as shown in Figure 9.3, there is usually a review of the EIS by the public and government to consider its accuracy and to recommend whether the proposal should go ahead or not. Different authorities and governments at the local, state or federal level have their own processes and procedures indicating timeframes for each review.

The EIS is normally carried out by the developer or proponent of the proposed development. The developer generally uses a consulting firm that would assemble a multi-disciplinary team to undertake the EIS. Although it might be argued that the developer might be biased, there are advantages in that the developer must pay for the EIS to be carried out, and since the developer has the relevant information it is more efficient for the developer to undertake the EIS. There is also the advantage

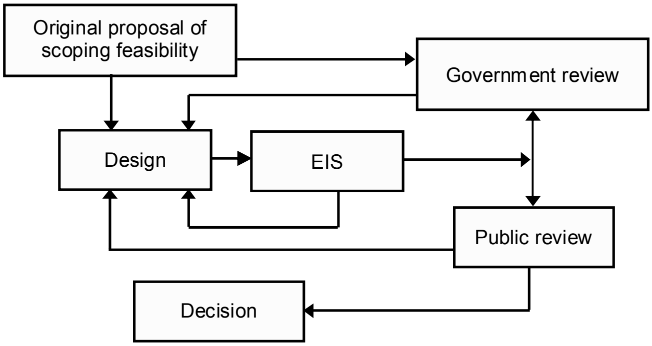

Figure 9.3 Simplified flowchart for an environmental impact assessment.

that the proponent can modify the design to reduce adverse impacts during the preparation of the EIS.

Most governments have regulations regarding EIAs and the reporting thereof, and give a formal procedure for the requirement of an EIA. For any significant project, an EIA would be required as part of the process of getting development approval. Generally a preliminary investigation, feasibility or scoping stage is performed prior to an EIA. It is very difficult to compare projects in terms of their environmental and social effects because of the many diverse factors involved. This contrasts with an economic comparison in which a single criterion such as NPV (see Chapter 8) gives an unambiguous ranking of projects. A number of techniques have been developed to assist in evaluating environmental and social factors. Some of these are listed in Table 9.3. Two of these that will be discussed here are the Battelle environmental index method and the Leopold matrix display technique. The Battelle method is a checklist method that uses scoring and weights. The Battelle and the Leopold methods have both been in use for many years. They are discussed here in order to illustrate the fundamental aspects of environmental assessments. Advanced modelling techniques allow greater complexity in assessments and modelling of scenarios.

The Battelle method

The Battelle method or Environmental index method was first designed for water resource development, (Dee et al., 1972; Dee et al., 1973; Martel and Lackey, 1977) but can be adapted for evaluation of a variety of types of projects. The principle lies in splitting the environmental impacts into four major categories: ecology; physical/chemical pollution; aesthetics; and human interest. These categories are divided into thematic data, as shown in Table 9.4. The full list is included in Appendix 9A.

Table 9.3 Main advantages and disadvantages of impact identification methods.

Impact Methods	Advantages	Disadvantages
Checklists -simple ranking and weighting	Simple to use and understand. Good for site selection. Good for priority setting.	Do not distinguish between direct and indirect impacts. Do not link action and impact. The process of incorporating values can be subjective, hence controversial.
Matrices	Links action and impacts. Good method for visual display of EIA results.	Difficult to distinguish the direct and indirect impacts. Potential for double-counting of impacts.
Networks	Links action to impacts. Useful in simplified form for checking for second order impacts. Handles direct and indirect impacts.	Can become very complex if used beyond simplified version.
Overlays	Easy to understand. Good display method. Good siting tool.	Address only direct impacts. Do not address impact duration or probability.
GIS and computer expert systems	Excellent for impact identification and analysis. Good for examining different scenarios-'experimenting'	Heavy reliance on knowledge and data. Often complex and expensive.

Source: (adapted from UNEP EIA Training Manual Edition 2, 2002).

These thematic data are divided into environmental indicators. For example, in a project discharging wastewater, the water pollution could be represented by: BOD; dissolved oxygen; faecal coliforms; inorganic carbon; pH; temperature; total dissolved solids; and turbidity of the receiving water and/or of the waste stream.

Table 9.4 Thematic types for the Batelle method.

Ecology (240)	Physical/ Chemical (402)	Aesthetics (153)	Human interest (205)
Species and populations	Water pollution	Land	Educational/scientific packages
Habitats and communities	Air pollution	Air	Historical packages
Ecosystems.	Land pollution	Water	Cultures
	Noise pollution	Biota	Mood/atmosphere
		Manmade objects	Life patterns

Note: the numbers in brackets are the weightings for each category.

Once the environmental indicators are chosen using Appendix 9A, the method follows three steps:

Step 1: transform environmental indicators into an environmental quality (EQ) rank. This usually requires expert advice to convert the environmental measurement to a scale of 0 to 1 (0 for poor quality and 1 for good quality). It is then possible to quantify environmental deterioration or improvement for the given project. A sample transformation is shown in Figure 9.4 for turbidity measured in Nephelometric Turbidity Units, transformed to the environmental quality index between 0 and 1.

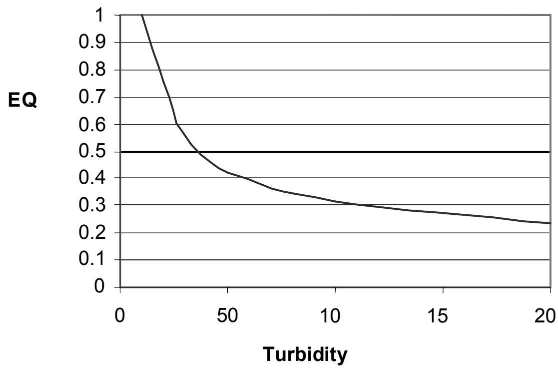

Figure 9.4 Environmental quality transformation.

Step 2: use the distributed Parameter Importance Units (PIU) which were developed by Dee et al. (1972). The relative importance of each parameter is reflected by distributing a total of 1,000 points among the indicators (e.g., a total of 240 for Ecology).

Step 3: complete the analysis for both the situation with and without the project in Environmental Impact Units (EIU). It can even reflect benefits or losses in terms of environmental conditions. The environmental impact is calculated using:

$$EI = \sum_{i=1}^{m} w_i \left[(V_i)_1 - (V_i)_0 \right] \tag{9.1}$$

where V_i is Environmental Quality (EQ) for each indicator i; the 1 subscript refers to the EQ with the project, and the 0 to the EQ without the project; w_i is the relative weight of indicator i; and m is the total number of indicators.

An advantage of this method is that it gives a comparative analysis of alternatives. Therefore, it is effective when a choice is to be made between projects. The problem of dealing with qualitative data is encountered in all assessments, and synthesis of information depends on the experience and professional judgement of the team undertaking the assessment and the stakeholders who have been consulted.

The Leopold matrix display technique

Matrix display techniques use a large matrix to summarize the environmental and social impacts of a proposed project, which may be given in a quantitative form. The Leopold matrix (Leopold et al., 1971) is an example. A disadvantage of the matrix display technique is that it can become difficult for users to absorb all of the information contained in the matrix.

The matrix lists a set of project actions in the first row and a set of environmental characteristics in the first column. Part 1 of Table 9.7 in Appendix 9A lists the project actions, while Part 2 lists the environmental characteristics. Other actions or environmental characteristics can be added as appropriate to give over 8800 possible interactions. For any project only some of the possible interactions will be relevant, but the actions and environmental characteristics do provide a useful checklist to ensure that all possible effects have been considered.

Each cell of the matrix for which an impact is likely to occur is identified and indicated by a diagonal line. An assessment is then made of the magnitude of the likely impact and a number between 1 and 10 is placed in the upper left-hand corner, with 1 representing the smallest magnitude and 10 the greatest (Leopold et al., 1971). This should be a factual assessment and not a value judgement. A number between 1 and 10 is placed in the lower right-hand corner of each cell to indicate the importance of the impact. This is a value judgement made by the evaluator. Leopold used the example of a proposal for the construction of highways and bridges. One consideration was that bridges may cause a large amount of bank erosion because geologic materials in an area are poorly consolidated. This may lead to the evaluator marking the magnitude of impact of highways and bridges on erosion at 6 or more. However, if the streams involved have high sediment loads and appear to be capable of carrying such loads without appreciable secondary effects, the effective importance of bridges through increased erosion and sedimentation will be relatively small and so marked as 1 or 2 in the lower right hand of the box. This would mean that while the magnitude of impact is relatively high, the importance of impact is not great.

Of course a matrix is just one example of summarizing the environmental impact of a proposed project. It must be supported by an environmental impact statement which discusses all impacts identified in the matrix. For example, Figure 9.5 shows a reduced impact matrix for a proposed phosphate mining lease in Los Padres National Forest, California (Leopold et al., 1971). The mining was to be an open-cut operation with ore processing on site, including crushing, leaching, and neutralization. The most important impact of the proposal was identified as the likely effect on the California condor, a rare and endangered species which exists in the region. The primary actions of concern were blasting and the increase in truck traffic, both of which were likely to disturb the nesting of the condor. In addition, sulphur fumes from mineral processing could have prevented the birds from landing to catch prey and hence present a danger to them.

These effects are shown in the row labelled “rare and unique species” as having a magnitude of 5 and an importance of 10. Other effects considered to be of moderate importance include the impact of industrial sites and buildings, highways and bridges, surface excavation, trucking, and the placement of tailings on the “wilderness qualities” of the area. The values in the boxes of a Leopold matrix are on an ordinal scale and cannot therefore be added or averaged. However, two or more projects can be compared in terms of the entries in an individual cell in the matrix to see which project will have the greater impact on that particular characteristic. Another approach, which avoids the use of numbers, is to use colour coding of the rankings and highlight those of importance with red flags.

Project actions

Environmental characteristics	Industrial sites and buildings	Highways and bridges	Transmission lines	Blasting and drilling	Surface excavation	Mineral processing	Trucking	Emplacement of taillings	Spills and leaks
Water quality					2/2	1/1		2/2	1/4
Atmospheric quality						2/3			
Erosion		2/2			1/1			2/2	
Deposition, sedimentation		2/2			2/2			2/2	
Shrubs					1/1				
Grasses					1/1				
Aquatic plants					2/2			2/3	1/4
Fish					2/2			2/2	1/4
Camping and hiking					2/4				
Scenic views and vistas	2/3	2/1	2/3		3/3		2/1	3/3	
Wilderness qualities	4/4	4/4	2/2	1/1	3/3	2/5	3/5	3/5	
Rare and unique species		2/5		5/10	2/4	5/10	5/10		
Health and safety							3/3		

Figure 9.5 Abbreviated Leopold matrix for a phosphate mining lease adopted from (Leopold et al., 1971).

Multi-objective and multi-criteria assessment approaches

Multi-objective approaches have been developed to quantify economic, environmental and social aspects of a project. These methods use data in an integrated way and have the capability of dealing with trade-offs among objectives.

Sustainability principles have yet to permeate the full range of methods and techniques used for project evaluation and assessment but they are becoming increasingly important. In planning and design situations where more than one objective is relevant, it is not usually possible to identify a single best solution. A design which is better in terms of its economic performance might not be as good in terms of its environmental and social impact. A design which has low environmental impact may involve low economic and social benefits. Compromise is the essence of good planning and design and is reflected in the push towards sustainability.

The role of the evaluator in multiple objective planning is to identify the most efficient designs (in terms of all objectives) and elucidate the tradeoffs between them. A central concept is that of *inferior* and *non-inferior* designs or plans. An example, using two objectives, may be a project where national economic development and environmental quality are considered as the objectives. Using these objectives, all feasible designs for a project could be evaluated and plotted in two-dimensional space, as shown in Figure 9.6.

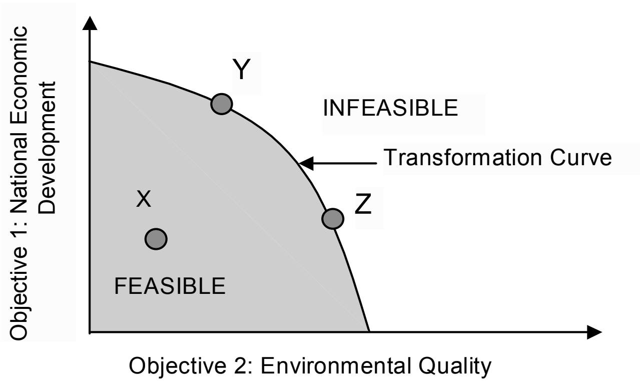

Figure 9.6 Multi-objective trade-off between alternatives.

By definition, an alternative A is inferior to alternative B if B ranks higher or equal to A for all objectives and higher for at least one objective. If A ranks higher than B for one objective and B higher than A for another, they are both non-inferior (for this pairwise comparison).

In Figure 9.6 design X is clearly inferior to design Y and can be discarded from further analysis. Designs Y or Z are non-inferior to each other and should therefore both be retained in the evaluation. Designs which are not inferior to any other are called "non-inferior" designs. A line joining all non-inferior designs is called the "Pareto Optimal frontier" or "transformation curve" (or "transformation surface" if there are more than two objectives). The transformation curve represents the boundary between feasible and infeasible designs in objective space.

The preferred design should lie on the transformation curve, provided all relevant objectives have been included in the analysis. The choice of a final design involves a value judgment as to the relative importance of the objectives and, in many cases, will involve a political decision.

The role of the evaluator in multiple objective planning is to identify the most efficient designs in terms of the objectives, and recognize the trade-offs among them. There are many techniques and software available for different applications and further considered in Section 12.7. An example of the development of a Multi-Objective Decision Support System (MODSS) for transport situations is described in some detail in Thoresen et al. (2001).

9.6 SOCIAL IMPACT

The environmental impact statement usually includes social impacts as well as effects on the physical and biological components of the environment. On the other hand, the USA Principles and Standards for Planning Water and Related Land Resources (USWRC, 1973) considered social well-being as a separate category of objectives. The social objective was defined as follows:

> *To enhance social well-being by the equitable distribution of real income, employment and population, with special concern for the incidence of the consequences of a plan on affected persons or groups; by contributing to the security of life, health and property; by providing educational, cultural and recreational opportunities; and by contributing to national security.* (USWRC, 1973)

If a full economic, environmental and social evaluation of a project is carried out, it is most important to avoid the double-counting of benefits or costs under more than one account. If, for example, an economic value is placed on lives saved through accident reduction and this is included in the *economic* evaluation of the project, it would not be appropriate to also highlight the number of lives saved in the *social* evaluation. Other examples of double-counting are discussed later in this section. The following types of social effects may need to be considered for a particular project:

- distribution of income;
- population distribution;
- employment;
- life, health, and safety;
- educational, cultural, and recreational opportunities;
- national security and emergency preparedness;
- displacement and relocation; and
- neighbourhood disruption and intrusion.

As with environmental effects, each social parameter can have its own ordinal or cardinal scale of measurement. The above effects are considered in turn.

Distribution of Income

In theory it is possible for a government to redistribute the benefits and costs of any public sector project among the various individuals or groups in society. This being the case, it can be argued that the role of the engineer or planner is to devise projects which maximise the total net benefits to the community and let the government decide how these benefits (and costs) will be distributed. However, this redistribution of benefits and costs is often not practicable because of the difficulties in identifying all affected groups and because of the administrative cost of carrying out the transfers. Redistribution of the benefits of engineering projects rarely occurs in practice.

It is therefore important that the distributional consequences of any major project be explicitly considered. Of particular relevance is the effect of the project on the income levels of certain target groups. These target groups may be distinguished on the basis of income (e.g. those living below the poverty level), race, sex, or geographic region.

It has been suggested by Weisbrod (1972) that the distributional question can be approached by placing explicit weights on the benefits and costs received by each group in the community. Traditional benefit-cost analysis gives the same weight to a dollar of benefits received by a pauper and by a millionaire. It is conceptually possible to give a higher weight to benefits or costs incurred by low-income earners and thus develop a single index of social welfare, using the following formula:

$$SW = \sum_{i=1}^{m} w_i [B_i - C_i] \qquad (9.2)$$

where SW is the index of social welfare; B_i is the present value of benefits received by group i; C_i is the present value of costs incurred by group i; w_i is the "social" weight of benefits or costs to group i; and m is total number of community groups. The difficulties of deciding on a set of weights and implementing this approach should be apparent.

Population Distribution

It has been argued that the redistribution of population throughout a region or the nation may be a major objective of government policy. This is particularly true in sparsely populated nations such as Australia. Major engineering projects in remote areas may contribute positively to the decentralization of population. The benefits of decentralization are related to enhanced national security and the benefits of rural versus urban living. High concentrations of population and industry are particularly vulnerable to attack by conventional or nuclear weapons. On the other hand, the settlement of remote areas leads to additional infrastructure costs for electricity supply, roads, railways, water supply, ports, and airfields.

Projects such as major irrigation developments which contribute to maintaining the size of the rural community may be supported on the grounds of the "healthier" lifestyle of country living. Continued growth of large cities at the expense of the surrounding country areas may also involve considerable increases in infrastructure costs in the city, as well as increases in the crime rate and other social problems. The negative aspects of population redistribution on individual families also need to be considered. These include the weakening of friendships and family ties and the stress associated with moving, setting up a new home, and adjusting to a changed lifestyle. The benefits of urbanization versus decentralization can vary from family to family depending on the independence of the family members.

Employment

One of the benefits cited by governments when new public works are announced is the effect that it will have on unemployment. A large engineering project may involve considerable employment in the implementation phase and also in the operations phase. Some people consider this an achievement in itself. In an economy with little or no unemployment, workers employed on a specific project will be taken from productive activities elsewhere in the economy. Therefore, the opportunity cost of their labour will be assessed as a *cost* to the project in the economic evaluation. In such a case, the number of people employed on the project is not a social benefit.

In an economy with high unemployment, some of the workers employed on the project may have been previously unemployed. As discussed in Section 8.8, previously unemployed labour has an opportunity cost to the project considerably less than the wage rate. If this effect is correctly taken into account in the economic evaluation of all projects, there is no need to further describe the employment implications of the projects, as this would be a double-counting of the same benefit.

The foregoing applies to public sector projects only. In the economic evaluation of private sector developments, all labour is costed at the actual wage rate paid. Thus, at times when there is less than full employment in the economy, the true net benefits of the project to society will be understated. In such cases it *is* valid to include the additional employment opportunities created by the project as part of the social evaluation.

The distributional consequences of employment opportunities may also be important; for example, in the creation of employment opportunities in depressed regions of the country or among disadvantaged groups such as ethnic, or low-income groups.

Life, Health, and Safety

Many engineering works contribute to saving lives, improving health, or increasing safety in the community. Typical examples are flood mitigation works, water treatment plants, sewage treatment, improved road alignments, grade separation, and coastal protection works. Attempts have been made to include the benefits of lives saved into the economic evaluation of public sector projects by placing an economic value on human life. Various methods have been suggested for estimating the economic benefits of saving human life. These include:

- the present value of the person's expected future earnings;
- a value imputed from political decisions which involve public expenditure aimed at reducing the number of deaths. For example, the government spends \$50 m in equivalent annual worth to upgrade railway crossings which will save an estimated 100 lives per year from fatal accidents. The implied value of saving one life is greater than or equal to \$50 m/100 (i.e. \$0.5 m per live saved); and
- a dollar amount which people are prepared to accept as compensation in order to put up with the additional risk of death involved in the project. For example, a proposed new chemical plant will increase the probability of death per year to each person in an adjoining town by 1 in 10,000. The economic cost of this increased risk is the sum over all people in the town of the minimum level of compensation which each person is prepared to accept in order to tolerate the increased risk. The same basis can be used for projects which *reduce* the probability of death for part of the community.

Practical and theoretical difficulties exist with all of these economic approaches. An alternative approach is to estimate the number of lives saved per year and treat this as a social benefit. Similar arguments apply to projects which increase or reduce the risk to public health or the chance of accidents occurring. Either a dollar value may be used in the economic evaluation or an estimated reduction in the risk may be included in the social evaluation.

Educational, Cultural, and Recreational Opportunities

It has already been stated that the distribution of income, and in particular to certain disadvantaged groups, is an important social effect. Similarly the distribution of educational, cultural, and recreational opportunities among regions and socio-economic groups may be an important consideration in evaluating a major project. For example, a major dam may provide a new recreational resource for fishing, boating, picnicking, and swimming (depending on the final end use of the water). The social benefits of these recreational uses may be as important as the economic benefits of the water provided by the dam. In some cases it may be advantageous to choose a dam site close to a population centre in order to increase the recreational opportunities for a particular group of people.

Educational and cultural values may be enhanced by engineering projects providing improved access to sites of historical, archaeological, or scientific interest. For example, a new road along the coast may provide improved access to some unique geological formations which are of considerable interest to the public, but controls need to be enforced; otherwise, the project could lead to the ruin of the formation.

National Security and Emergency Preparedness

A new road or railway could have important consequences for national security. Such benefits are difficult to quantify in economic terms and, in fact, only become apparent in times of armed conflict. However, they may be an important social consideration in the evaluation of a project.

Emergency preparedness requires, for example, the provision of a flexible water supply, electricity grid, and road and rail network. The provision of a single dam to supply water to a city or a single power station to supply electricity may be economically efficient under normal circumstances but could be disastrous in the event of a catastrophe such as major technical failure, earthquake, hurricane, nuclear explosion, or act of sabotage. The provision of some redundancy in all engineering systems is a good rule to follow.

Displacement and Relocation

Engineering projects in urban areas may involve the displacement and relocation of some houses, and commercial or industrial buildings. A typical example arises from the land acquisition associated with an improved transport link, such as a freeway, arterial road, tramway, or railway. It is common practice for the households or firms displaced to be suitably compensated for the loss of their land, home, shop, or factory.

It is often argued that the loss of physical assets is suitably compensated for by the payment of fair market value. However, such an argument ignores the fundamental distinction between value in exchange and value in use. Consider the market for houses of a particular age and quality. If the current market price for such houses is P_o, this may be called the “value in exchange of the property”. Clearly all homeowners who are prepared to sell at this price or less will put their houses on the market. However, there are many homeowners who are not willing to sell at the price P_o. To these people, the value in use of the house exceeds its value in exchange. If a road authority were to compulsorily acquire such a house and pay compensation equal to P_o, the homeowner would clearly suffer a loss of utility. Full compensation should cover the value in use of the asset and would usually exceed P_o by a significant margin. A similar argument applies to commercial and industrial properties.

The difference between value in use and value in exchange of a house includes an allowance for the stress of moving, disruption of social ties, the cost of finding a new house, and changes in accessibility and travel costs at the new location. In practice such costs are difficult to assess and considerable negotiation may be required with the property owners.

The compensation costs for displaced households and firms are a true opportunity cost to a project and should be included in the economic evaluation, rather than the social evaluation.

Neighbourhood Disruption and Intrusion

An engineering project may involve significant disruption and/or intrusion into a community. This is particularly true of transportation corridors which can sever a cohesive community or produce intrusive impacts in the form of noise, vibration, air pollution, or aesthetic degradation. A sense of community is often very strong and may be centred on facilities such as schools, shopping centres, the town hall, or parks. Proposals which isolate one part of the community from another may receive considerable opposition from local community groups. Transport corridors should be planned to provide the minimum disruption to communities and ensure that adequate safe crossings such as overpasses or underpasses are provided for pedestrians and cyclists.

The principle of compensation described in the previous section can be applied to neighbourhood disruption and intrusion, but it is very difficult to define the loss of utility for an entire community. Attempts have been made to assess the economic effects of noise due to airports, highways, or railways by assessing the lower property values adjacent to these facilities. If such an approach is taken, these social effects can be included as a cost in the economic evaluation.

9.7 SOCIAL ASSESSMENT TOOLS AND METHODS

An extremely important facet of undertaking any project analysis involves the participation of interested stakeholders. This is an area where many engineers will be called on to manage and participate with specialists who work in the social assessment area. A basic knowledge of the methods available for undertaking such project analyses is given in the UNEP EIA Training Manual (UNEP, 2002). A number of methods are described below which allow social concerns to be discovered and to determine local knowledge concerning a proposed project.

Analytical tools

Stakeholder analysis is an entry point to Social Impact Assessment (SIA) and participatory work. It addresses strategic questions, e.g. Who are the key stakeholders? What are their interests in the project or policy? What are the power differentials between them? What relative influence do they have on the operation?

This information helps to identify institutions and relationships which, if ignored, can have negative influence on proposals or, if considered, can be built upon to strengthen them.

Gender analysis focuses on understanding and documenting the differences in gender roles, activities, needs and opportunities in a given context. It highlights the different roles and behaviour of men and women. These attributes vary across cultures, class, ethnicity, income, education, and time; and so gender analysis does not treat men or women as a homogeneous group.

Data Review of information from previous work is an inexpensive, easy way to narrow the focus of a social assessment, to identify experts and institutions that are familiar with the development and context, and to establish a relevant framework and key social variables in advance for the project.

Community-based methods

The participatory approach aims to ascertain local knowledge and actions. It uses group exercises to enable stakeholders to share information and to develop plans. These techniques have been employed successfully in a variety of settings to enable local people to work together to plan community-appropriate developments. Attributes of self-esteem, associative strength, resourcefulness, action planning and responsibility for follow-through are important to achieve a participatory approach to development. Generally there is a philosophy of empowerment of the stakeholders to enable people to adopt responsibility for outcomes. It can best be described as development of teambuilding skills and learning from local experience rather than from external experts. Other participatory consultation methods include selecting a sample of stakeholders to ensure that their concerns are incorporated into the assessment. This selection is for the purposes of giving voice to the poor and other disadvantaged stakeholders.

Other Participatory Methods

Role playing helps people to be creative, open their perspectives, understand the choices that another person might face, and make choices free from their usual responsibilities. This exercise can stimulate discussion, improve communication, and promote collaboration at both community and agency levels.

Wealth ranking (also known as “well-being ranking” or “vulnerability analysis”) is a visual technique to engage local people in the rapid data collection and analysis of social stratification in a community (regardless of language and literacy barriers). It focuses on the factors which constitute wealth, such as ownership of or right to use productive assets/resources, their relationship to locally powerful people, labour and indebtedness.

Mapping is an inexpensive tool for gathering both descriptive and diagnostic information. Mapping exercises are useful for collecting baseline data on a number of indicators as part of a beneficiary assessment or rapid appraisal, and can lay the foundation for community ownership of development planning by including different groups and making them aware of the implications of the project.

Needs Assessment draws out information about people's needs and requirements in their daily lives. It raises participants' awareness of development issues and provides a framework for prioritising actions and interventions. All sectors can benefit from participating in a needs assessment, as can trainers, project staff and field workers.

Tree Diagrams are multi-purpose, visual tools for narrowing and prioritising problems, objectives or decisions. Information is organized into a tree-like diagram. The main issue is represented by the trunk, and the relevant factors, influences and outcomes are shown as roots and branches of the tree. Other techniques such as mind mapping, as discussed in Chapter 6, can also be used for this purpose.

Observation and interview tools

Focus group meetings are a rapid way to collect comparative data from a variety of stakeholders. They are brief meetings - usually one to two hours - with many potential uses, e.g. to address a particular concern; to build community consensus about implementation plans; to cross-check information with a large number of people; or to obtain reactions to hypothetical or intended actions.

Workshop-based methods encourage participatory planning and analysis throughout the project life cycle. A series of stakeholder workshops tend to be held to set priorities, and integrate them into planning, implementation and monitoring. Building commitment and capacity is an integral part of this process (UNEP, 2002). These stakeholder workshops are in common use for many infrastructure and resource projects throughout the world.

9.8 SUMMARY

Engineers have a primary responsibility to society when developing infrastructure and this can override their responsibility to the client, depending on the Code of Ethics being applied. The responsibility entails evaluating environmental and social effects of the project. Many consulting engineering firms are required to perform Environmental Impact Assessments for projects that they plan and design. In many cases, the engineer will be actively involved in stakeholder consultations, giving presentations to community groups as well as professional groups. To do this, communication skills and knowledge of the environmental assessment process are essential. Future work for both private development and for government infrastructure will be undertaken using sustainability principles to guide the development of the project. The role of the engineer in planning is to identify the most efficient designs, in terms of all the objectives, and recognize the trade-offs among them.

Professional engineering institutions worldwide have embedded sustainability within their charters and codes of ethics, but progress to achieve these ideals has in the past been thwarted by little political and legislative assistance, but this is changing. The production of CO_2 and the linkage to climate change are the main driving forces for the way industry and government are viewing sustainability. The integration of sustainable energy systems with a process of closed-loop systems for resource use is seen as a key element in approaching sustainability.

PROBLEMS

9.1 Locate three reports which are aligned with the Global Reporting Initiative. Compare and contrast the data contained within them. How readily does the data enable comparisons between the different organisations?

9.2 Select two of the 2015 Sustainable Development Goals and explain how progress towards the targets could be measured. How could these measurements inform the overall assessment of progress?

9.3 A study is being carried out on alternative energy sources for the future generation of electricity in your state. The energy sources include coal, natural gas, nuclear, solar and wind energy (and combinations thereof). List and describe the environmental and social effects which would need to be considered when comparing these alternatives. Illustrate use of the Leopold matrix display technique by deriving the matrix relevant to the use of coal as the primary energy source for your city, mined from a regional centre and transported by rail.

9.4 A winery is proposing to expand its operations with the development of a new processing facility. The winery is confident with its proposal since it includes some additional treatment of the wastewater before it is discharged into a nearby waterway, although the machinery used will create increased noise in the quiet rural setting and some venting of NO and NO_2 (reported as nitrous oxides, NO_x). Details of the air and water discharges, and the noise produced are given in Table 9.5. The results of an expert panel assessing the environmental quality of the relevant parameters are included in Figure 9.7.

Table 9.5 Discharge estimates for winery and its proposed development.

Water Quality Parameter	Existing Operations	Option 1
Turbidity (NTU)	30	20
Temperature (°C)	20	22
DO (mg/L)	8	6
Ph	8	7
Noise (dB)	5	20
Nitrous Oxides (NO_x) (mg/L)	5	15

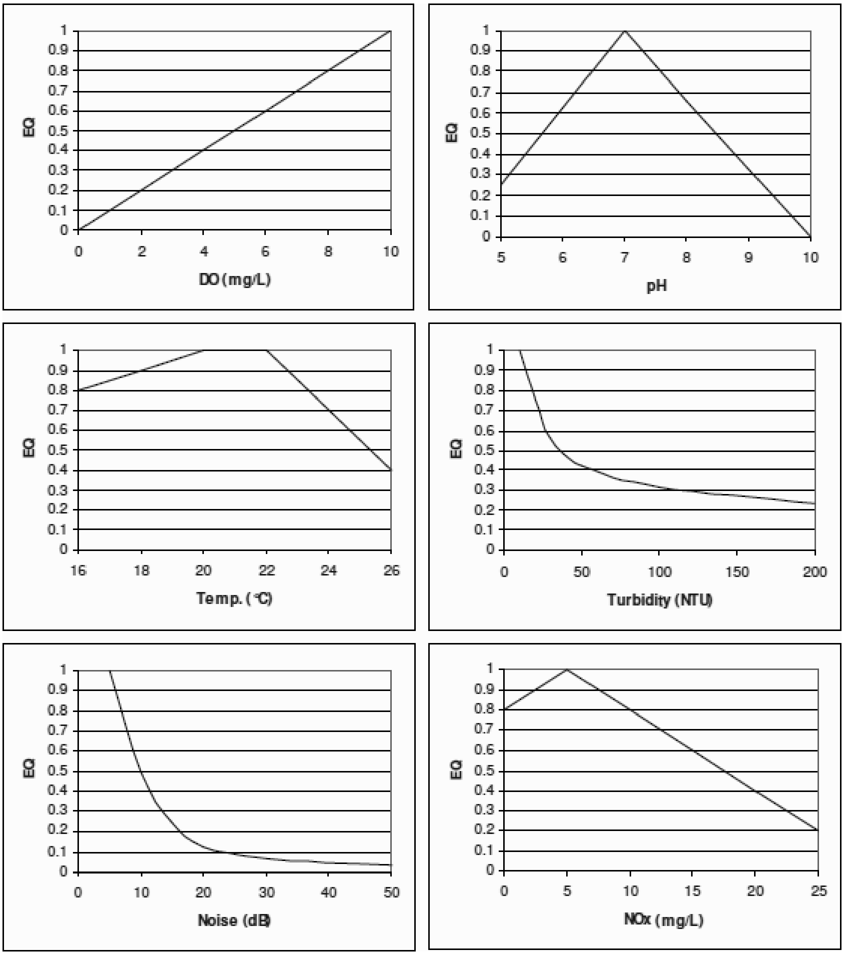

Figure 9.7 Environmental quality of various environmental parameters.

Use the Environmental Index System to suggest whether, on the basis of the environmental information provided, the winery should be allowed to expand its operations. List, and discuss in 20 words or less (each), the six most important social issues that should be considered in the environmental assessment of the proposal.

9.5 In 1974, Ehrlich and Ehrlich published a book, *The End of Affluence*, in which they proposed a "nutritional disaster that seems likely to overtake humanity in the 1970s (or, at the latest, the 1980s). Before 1985 mankind will enter a genuine age of scarcity" in which "the accessible supplies of many key minerals will be nearing depletion." Comment on why this did not happen and whether it will occur by 2020 as many environmental activists are predicting?

9.6 A wave energy farm is to be constructed 1 km off shore to supply both electrical energy and desalinated water to a coastal community of 2,000 people. You are to prepare a scoping study which would include the activities of the development with the potential environmental impacts and suggestions of mitigating solutions to these impacts. There are a number of wave energy systems being trialled around the world. Choose two of these systems and compare with each other.

9.7 Search environmental modelling journals and find two papers, published since 2015, which describe an environmental modelling approach. How do these compare with the early models described in the chapter?

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APPENDIX 9A THE BATTELLE CLASSIFICATION AND LEOPOLD MATRIX

Table 9.6 The Battelle Environmental Classification for Water-Resource Development Projects (Dee et al., 1973). The Bracketed Numbers are the Distributed Parameter Importance Units, i.e. Relative Weights.

ECOLOGY (240)
Terrestrial Species & Populations
-Browsers and grazers (14)
-Crops (14)
-Natural vegetation (14)
-Pest species (14)
-Upland game birds (14)
Aquatic Species & Populations
-Commercial fisheries (14)
-Natural vegetation (14)
-Pest species (14)
-Sport fish (14)
-Water fowl (14)
Terrestrial Habitats & Communities
-Food web index (12)
-Land use (12)
-Rare & endangered species (12)
-Species diversity (14)
Aquatic Habitats & Communities
-Food web index (12)
-Rare & endangered species (12)
-River characteristics (12)
-Species diversity (14)
Ecosystems
-Descriptive Only

PHYSICAL/CHEMICAL (402)
Water Quality
-Basin hydrologic loss (20)
-Biochemical oxygen demand (25)
-Dissolved oxygen (31)
-Faecal coliforms (18)
-Inorganic carbon (22)
-Inorganic nitrogen (25)
-Inorganic phosphate (28)
-Pesticides (16)
-pH (18)
-Streamflow variation (28)
-Temperature (28)
-Total dissolved solids (25)
-Toxic substances (14)
-Turbidity (20)
Air Quality
-Carbon monoxide (5)
-Hydrocarbons (5)
-Nitrogen oxides (10)
-Particulate matter (12)
-Photochemical oxidants (5)
-Sulphur oxides (10)
-Other (5)
Land Pollution
-Land use (14)
-Soil erosion (14)
Noise Pollution
-Noise (4)

AESTHETICS (153)
Land
-Geologic surface material (6)
-Relief & topographic character (16)
-Width and alignment (10)
Air
-Odour and visual (3)
-Sounds (2)
Water
-Appearance of water (10)
-Land & water interface (16)
-Odour and floating material (6)
-Water surface area (10)
-Wooded /geologic shoreline (10)
Biota
-Animals -domestic (5)
-Animals -wild (5)
-Diversity of vegetation types (9)
-Variety within vegetation types (5)
Man-Made Objects
-Man-made objects (10)
Composition
-Composite effect (15)
-Unique composition (15)

HUMAN INTEREST /SOCIAL (205)
Education/Scientific
-Archeological (13)
-Ecological (13)
-Geological (11)
-Hydrological (11)
Historical
-Architecture and styles (11)
-Events (11)
-Persons (11)
-Religions and cultures (11)
-'Western Frontier' (11)
Cultures
-Indians (14)
-Other ethnic groups (7)
-Religious groups (7)
Mood/ Atmosphere
-Awe/inspiration (11)
-Isolation/solitude (11)
- Mystery (4)
-'Oneness' with nature (11)
Life Patterns
-Employment opportunities (13)
-Housing (13)
-Social interactions (11)

Table 9.7 The Leopold Matrix (Leopold et al., 1971). Part I Lists the Project Actions; Part 2 Lists the Environmental Characteristics and Conditions

PART 1: Project Actions (Horizontal Axis of Matrix)

A. MODIFICATION OF REGIME
a) Exotic flora or fauna introduction
b) Biological Controls
c) Modification of habitat
d) Alteration of ground cover
e) Alteration of ground-water hydrology
f) Alteration of drainage
g) River control and flow codification
h) Canalization
i) Irrigation
j) Weather modification
k) Burning
l) Surface or paving
m) Noise and vibration

B. LAND TRANSFORMATION AND CONSTRUCTION
a) Urbanization
b) Industrial sites and buildings
c) Airports
d) Highways and bridges
e) Roads and trails
f) Railroads
g) Cables and lifts
h) Transmission lines, pipelines and corridors
i) Barriers, including fencing
j) Channel dredging and straightening
k) Channel revetments
l) Canals
m) Dams and impoundments
n) Piers, seawalls, marinas, and sea terminals
o) Offshore structures
p) Recreational structures
q) Blasting and drilling
r) Cut and fill
s) Tunnels and underground structures

C. RESOURCE EXTRACTION
a) Blasting and drilling
b) Surface excavation
c) Sub-surface excavation
d) Well drilling and fluid removal
e) Dredging
f) Clear cutting and other forestry
g) Commercial fishing and hunting

D. PROCESSING
a) Farming
b) Ranching and grazing
c) Feed lots
d) Dairying
e) Energy generation
f) Mineral processing
g) Metallurgical industry
h) Chemical industry
i) Textile industry
j) Automobile and aircraft
k) Oil refining
l) Food
m) Lumbering
n) Pulp and paper
o) Product storage

E. LAND ALTERATION
a) Erosion control and terracing
b) Mine sealing and waste control
c) Strip mining rehabilitation
d) Landscaping
e) Harbour dredging
f) Marsh fill and drainage

F. RESOURCE RENEWAL
a) Reforestation
b) Wildlife stocking and management
c) Groundwater recharge
d) Fertilization application
e) Waste recycling

G. CHANGES IN TRAFFIC
a) Railway
b) Automobile
c) Trucking
d) Shipping
e) Aircraft
f) River and canal traffic
g) Pleasure boating
h) Trails
i) Cables and lifts
j) Communication
k) Pipeline

H. WASTE DISPOSAL AND TREATMENT
a) Ocean dumping
b) Landfill
c) Emplacement of tailings, spoil and overburden
d) Underground storage
e) Junk disposal
f) Oil-well flooding
g) Deep-well emplacement
h) Cooling-water discharge
i) Municipal waste discharge including spray irrigation
j) Liquid effluent discharge
k) Stabilization and oxidation ponds
l) Septic tanks
m) Stack and exhaust emission
n) Spent lubricants

I. CHEMICAL TREATMENT
a) Fertilization
b) Chemical de-icing of highways, etc.
c) Chemical stabilization of soil
d) Weed control
e) Insect control (pesticides)

J. ACCIDENTS
a) Explosions
b) Spills and leaks
c) Operational failure

PART 2: Environmental Characteristics and Conditions (Vertical Axis of Matrix)

A. PHYSICAL AND CHEMICAL CHARACTERISTICS

1. *Earth*
a) Mineral resources
b) Construction material
c) Soils
d) Landform
e) Force fields and background radiation
f) Unique physical features

2. *Water*
a) Surface
b) Ocean
c) Underground
d) Quality
e) Temperature
f) Snow, Ice, and permafrost

3. *Atmosphere*
a) Quality (gases, particulates)
b) Climate (micro, macro)
c) Temperature

4. *Processes*
a) Floods
b) Erosion
c) Deposition (sedimentation, precipitation)
d) Solution
e) Sorption (ion exchange, complexing)
f) Compaction and settling
g) Stability (slides, slumps)
h) Stress-strain (earthquake)
i) Recharge
j) Air movements

B. BIOLOGICAL CONDITIONS

1. *Flora*
a) Trees
b) Shrubs
c) Grass
d) Crops
e) Microflora
f) Aquatic plants
g) Endangered species
h) Barriers
i) Corridors

2. *Fauna*
a) Birds
b) Land animals including reptiles
c) Fish and shellfish
d) Benthic organisms
e) Insects
f) Microfauna
g) Endangered species
h) Barriers
i) Corridors

C. CULTURAL FACTORS

1. *Land use*
a) Wilderness and open spaces
b) Wetlands
c) Forestry
d) Grazing
e) Agriculture
f) Residential
g) Commercial
h) Industrial
i) Mining and quarrying

2.*Recreation*
a) Hunting
b) Fishing
c) Boating
d) Swimming
e) Camping and hiking
f) Picnicking
g) Resorts

3. *Aesthetics and Human Interest*
a) Scenic views and vistas
b) Wilderness qualities
c) Open space qualities
d) Landscape design
e) Unique physical features
f) Parks and reserves
g) Monuments
h) Rare & unique species or ecosystems
i) Historical or archaeological sites and objects
j) Presence of misfits

4. *Cultural Status*
a) Cultural patterns (lifestyle)
b) Health and safety
c) Employment
d) Population density

5. *Man-Made Facilities and Activities*
a) Structures
b) Transportation network (movement, access)
c) Utility networks
d) Waste disposal
e) Barriers
f) Corridors

D. ECOLOGICAL RELATIONSHIPS
a) Salinization of water resources
b) Eutrophication
c) Disease-insect vectors
d) Food chains
e) Salinization of surficial material
f) Brush encroachment
g) Other