Chapter 1

Making decisions: a difficult problem

AC, AN and RSS

The evolution of a natural system that is subject to anthropic pressure is well described by the DPSIR framework, proposed by the European Environmental Agency (EEA) and reproduced in Figure 1.1 (EEA, 1999, see also OECD, 1994 and UNCSD, 1996). The *Drivers* generate *Pressures* that change the *State* of the system. This variation produces *Impacts* on society, which reacts by devising and implementing *Responses*, which can be directed at the Drivers, as well as the Pressures, the State or the Impacts themselves.

The following example is useful to clarify the framework[1]: consider an enchanting lake, surrounded by fields, forests, a fishing village and a few small hotels.[2] The Drivers are the agricultural, industrial and domestic practices. They produce a flow (Pressure) of nitrogenous substances that reaches the lake, through agricultural land run off, or through direct or indirect discharge from the sewage system. It follows that there is an increase in the trophic level of the lake, which induces algal blooms, anoxic conditions and mass fish death, and so, a variation in the State of the lake. In this way two Impacts are produced: a reduction in fishing activity and a loss of the lake's appeal to tourists. In order to respond to the fishermen's and hotel-keepers' discontent, the Environmental Agency (EA) must design an intervention (Response). It can choose among different forms: issue a regulation regarding the use of nitrogenous fertilizers in agriculture (arrow 1 in Figure 1.1), create a stage for the removal of phosphorous in the treatment plant that purifies the sewage prior to discharge (2), collect the algae when necessary or inject oxygen at a certain depth to prevent lake waters from becoming anoxic (3), or simply introduce a monetary compensation (4) for the damage. In general terms, the EA is not limited to choosing only one of these *interventions*, each of which can be realized in different forms and degrees: it can also select a combination of them, in an integrated and coordinated package, that we will call *alternative*.[3]

[1] An example of real world application of the DPSIR framework within the WFD context is outlined in Appendix A1.

[2] In what follows we will refer to this example as the 'enchanting lake' example.

[3] A specification for readers who are familiar with negotiation theory: in the literature (see for example Raiffa et al., 2002) there is a distinction between the alternatives that a Party can pursue alone (i.e. without reaching a negotiated agreement), and those that are subject to negotiations, because they contain actions that can be carried out only after an agreement has been reached. The term 'alternative' is reserved for the first, while the term 'option' is used for the second. We will not make this distinction (except for Appendix A10 on the CD) and we will use the term 'alternative' to designate both of them.

In some contexts the term 'programme of measures' is used instead of 'alternative'.

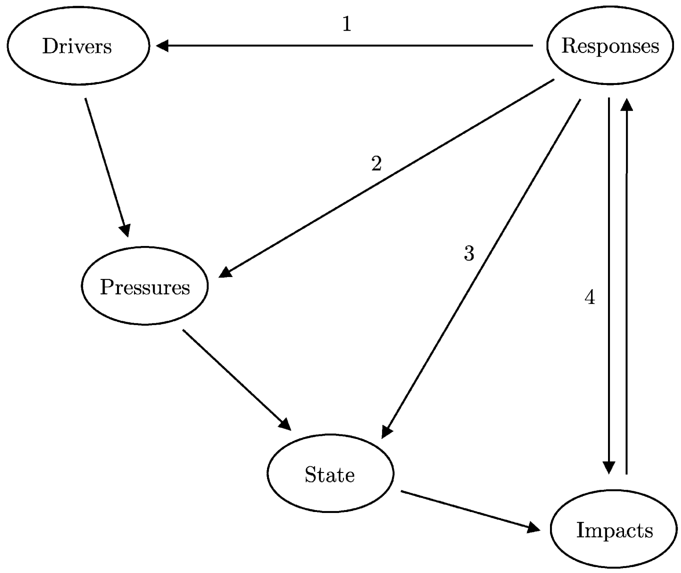

Figure 1.1: The DPSIR framework.

In practice, the same system will require different Responses as time goes by and the context changes. Therefore, very rarely the alternative is established once and for all, more often interventions occur in cycles, as in Figure 1.2. Each cycle is a sequence of events: a *planning* phase, in which an alternative is chosen, its *implementation*, and the *management* of the modified system for a period of time afterwards, during which the system behaviour, i.e. the Impacts produced, is monitored (*monitoring*). When such impacts require a new response, a new cycle begins.

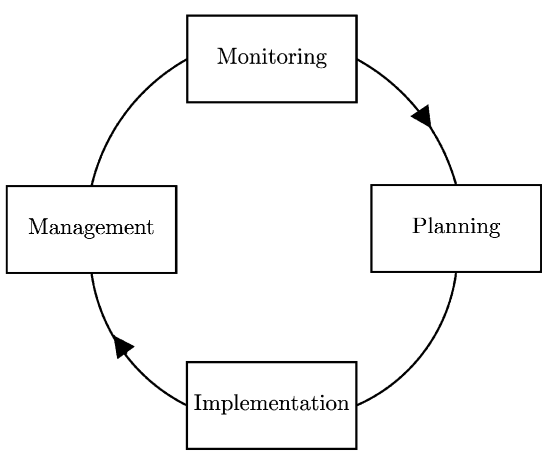

Figure 1.2: The intervention cycle.

The choice of an alternative constitutes a *Planning Problem*, the solution of which requires a *procedure* to be established. This chapter is dedicated to the individuation of the latter, but before proceeding, an effort is made to clarify what kind of interventions we are talking about and what relationship they have with actions and decisions.

1.1 Interventions, actions and decisions

The interventions we are concerned within this book are generally those that are defined by a *Project* (i.e. the choice of an alternative that permits the achievement of given goals), but they could also be those that make up a *Plan* (substantially a project, but with a broader range, that usually deals with a wider area and considers larger scale decisions, but at a lower level of detail), a *Policy*[4] (less detailed than a Plan and at a level that is more strategic and less operative) or a *Program* (a set of Projects, organized in time, through which a Plan or Policy is implemented). In practice, the boundaries among these terms are not well defined and are therefore subjective. For this reason, sometimes Projects may seem like Plans, or Policies may seem like Projects. Independently of the name that is adopted, the essential nature of the thing does not change. In the text that follows the term *Project* will (almost) always be used. As is common practice, it will sometimes be employed also to denote the decision-making process.

We are now ready to give a more precise idea of the types of interventions that we are thinking about when we speak of Projects: these are the different approaches that can be used to reach the Goal that has been set. In practice, interventions can vary greatly from case to case and be quite case-specific. We give the following general guidelines for identifying possible interventions in any given case: do not exclude any intervention without first evaluating it, even if at first glance it is not very ‘orthodox’; and avoid, as much as possible, interventions that for sure will preclude others in the future. As it would be impossible to make a list of all the possible interventions, we prefer to exemplify with two projects.

1.1.1 A first example: the Egyptian Water Plan[5]

The Egyptian system and the reasoning behind the Plan are described in the box on page 6. In brief, its aim is to improve the country’s quality of life by targeting water availability, bearing in mind the need for environmental sustainability. The Plan covers a period of fifty years into the future.

Given the significant extension of the time horizon, it is necessary to consider all the activities that may affect the availability or quality of water resources in the long run. For example: the increase of urbanized areas, which follows from population growth and takes fertile land away from agriculture, and industrial development, which increases the demand for water and depletes the available resources through pollution. The ‘quantity’ of the resource is in fact strictly connected to its ‘quality’: for water to be usable, appropriate standards must be passed, which depend on its use. Not only must the quantity and quality of water in bodies of water be considered, but also the effects of water on soils (salinization, desertification), on crops (increase or loss of productivity, bioaccumulation of toxins), on human health (diffusion of water-borne pathogenic agents) and on the natural state and biodiversity of the environment. Finally, given that the largest portion of the demand is due to irrigation,

[4]Not to be confused with the meaning of the term that will be defined in Section 2.1.1.2.

[5]Following Nardini and Fahmy (2005), with a few modifications for didactic requirements.

The Egyptian Water Plan

System description For Egypt, water is the most important natural resource, and at the same time the one at the greatest risk. Egypt's groundwater reserves are in fact very limited. The water required for domestic use, industrial activities and irrigation comes from the Nile. This is regulated by the High Aswan Dam that creates Lake Nasser, which collects the flow from a vast catchment. It is expected, however, that in following years the flow will decrease, not only because of the climate change that is probably occurring, but mostly because many towns in the catchment area foresee an increase in the amount of water drawn from the Nile to meet the needs of a growing population. Problems come not only from the limited quantity of the resource (the entire volume supplied by Lake Nasser is consumed before it reaches the sea), but also from its quality, which is depleted by many sources of pollution. It is legitimate therefore to affirm that the quantitative and qualitative scarcity of water resources is threatening to become the principal factor limiting the future development of the country.

Project proposal The water resource problem in Egypt has been a subject of study for many years (Elarabawy et al., 1998; NAWQAM, 1999) and a great number of proposals have been put forward. They are, nevertheless, primarily sectorial and the positive effects that they produce in a given sector are often accompanied by negative effects in others. For example, using recycled (polluted or brackish) water for irrigation makes it possible to reallocate precious water volumes from agriculture to domestic uses. However, if this practice is abused the fertility of the land is reduced in the medium to long term. The development or intensification of agricultural practices in one zone can bring about a reduction in the availability of water in another. The introduction of more efficient irrigation techniques can slow the recharge rate of aquifers and therefore reduce their usability downstream or in the future. In order to consider this complicated tangle of factors, the Egyptian Government decided to prepare a National Water Plan, which defines the terms and timescale for the interventions to be carried out and the measures designed to guarantee the water resources that the country will need in the medium to long term. The Egyptian Government's objective is to improve quality of life for the country over the next 50 years. The Government also wants the plan to be economically efficient, environmentally sustainable, financially and politically feasible, and socially equitable so that it guarantees national security.

among the interventions to be considered one should include all those which affect farmers' choices. These can be laws about land use, provisions for water saving, economic incentives and disincentives, and fixing prices of production commodities and foodstuffs.

Below is a summary of the options for intervention that can be considered within Egypt itself, excluding political agreements that could be established with the States of the Nile basin to improve the quantity and quality of water that reaches Lake Nasser. This summary should not be considered either absolute or exhaustive. In a different geographic situation or with other aims it would be appropriate to eliminate some of the headings and add others.

- **Interventions to locally increase water availability**
  - constructing desalinization plants for brackish and marine water;
  - constructing structures for exploiting rainfall and flash floods;
  - constructing waste water recycling plants;
  - constructing water treatment plants to provide drinking water;
  - constructing pumping stations for superficial or deep aquifers;
  - installing pumps for lifting water from interceptor canals into the irrigation network;
  - improving irrigation network efficiency, e.g. by coating the earth canals;
  - improving drinking water distribution efficiency, e.g. by reducing seepage and leakage;
  - extending the irrigation network into lands reclaimed from the desert;
  - changing irrigation method: a shift from the flooding method, which is extremely water consumptive, to the sprinkler or drip methods.[6]

- **Interventions to safeguard the quality of the environment**
  - constructing domestic and industrial wastewater treatment plants;
  - improving the drainage network to counteract the salinization of soils;
  - enacting laws that establish quality standards for effluents or receiving bodies.

- **Regulation policies**[7]
  - defining regulation policies for Lake Nasser, the only surface reservoir that serves Egypt;
  - defining regulation policies for the aquifers (define the extractable volumes from each of them according to the month of the year and the condition of Lake Nasser);
  - defining distribution policies between land districts.

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[6] One may ask why not simply decide to change over to the drip method at one fell swoop, which would drastically reduce consumption and might finally allow Egypt's thirst to be satisfied. There are several reasons. First of all, the high costs of the equipment, and the fact that not all soils are suited to or able to sustain the crops that are compatible with drip irrigation. In addition, the surplus water required by the flooding method is not all lost. A great deal filters into the water table, from where it evaporates less than from the canals, and from where it is then pumped to be reused downstream. Lastly, there is cultural inertia. The agricultural community is structured around the extremely dense network of irrigation and interceptor canals, the very structure of the flooding method, which delimits the plots of land. The people's way of life is linked to this structure. The modification of this state of affairs requires a cultural education programme which can be a slow process. This should be considered in the context of an integrated intervention.

[7] A regulation policy is a procedure that defines the rate of flow to release from a reservoir or to divert at a diversion dam, or to pump from an aquifer (see page 40) as a function of the data acquired from the information system.

- **Interventions aimed at guiding behaviour**
  - sizing areas used for particular crops; imposing crop rotation in the first years, in lands reclaimed from the desert; imposing taxes/subsidies on some crops;
  - setting limits to urban expansion;
  - improving irrigation efficiency through education programs and economic incentives;
  - setting taxes/subsidies for the use of chemical products;
  - setting quotas, taxes/subsidies for importing/exporting certain foodstuffs;
  - setting prices for products controlled by the government;
  - defining tariff schemes[8] for water service users, both domestic and industrial;
  - defining incentives for the settlement of farmers in reclaimed lands.

Note that all these interventions have (and must have) something in common: they can all be carried out and managed by the organization that commissions the Plan: the Egyptian Government.

1.1.2 A second example: controlling hydraulic risk[9]

The management of hydrogeological instability and especially the risk of flooding are of vital importance in many countries. Traditionally, the interventions that are considered are:

- **Structural interventions for hydraulic protection and regulation**
  Among the most common are the construction of flood detention areas,[10] detention basins,[11] dry dams,[12] dikes, riverbank defences, flood diversion canals and rectification of the river channel.

All these interventions have reduced the naturalness and beauty of the water courses and the landscape, they have impoverished biodiversity and, albeit surprising, they often have not reduced the risk of flooding. This is due to two reasons: the first is that in the 'safety' zones land use has intensified, increasing the potential damage. The second is that the interventions have increased the flood peaks in downstream transects, thus worsening the situation, because they have reduced the time of concentration and the detention capacity of the river channel. Experience has demonstrated that these interventions are too often neither sufficient, nor effective, nor efficient, nor sustainable. As a result, in the last decade in many countries a new approach is emerging, which aims at a generalized renaturalization and is based on the following actions:

- **Interventions to reduce the potential damage**
  Avoiding and eliminating the presence of assets in flood risk zones, establishing binding building regulations and/or promoting the delocalization of settlements already present through regulations and economic incentives.

[8] The rules that establish how much each user must pay for the water used as a function of the volume of water withdrawn, of the withdrawal period, and of the category to which the user belongs.

[9] This section is based upon Nardini (2005).

[10] Portions of land that are dedicated to the temporary storing of the volumes of water that overflow from a water course, thus lowering the peak level of the flood and thus alleviating the flooding risk for areas downstream.

[11] These are flood control structures similar to detention areas, but artificially controlled: they typically include banks, which separate the river channel from the flood zone, a spillway that regulates the intake of water from the river channel, and a drainage system.

[12] A non-regulated dam that, in normal conditions, holds back no water and allows the river to flow freely. During periods of intense flow, which would otherwise cause flooding downstream, the dam temporary holds back the excess water, releasing it downstream at a controlled rate.

- **Interventions to increase storage capacity**

  Modifying the general situation of the territory: reafforesting; constructing retention basins for storm water in urban zones; reducing the impermeability of urban ground, creating draining surfaces in parking lots, in squares, and on the roofs of buildings (*green roofs*); and establishing incentives/disincentives to drive the actions of the private sector in this direction.

  Reestablishing space for rivers to flood, to modify morphology and to meander: moving or eliminating banking, rectifications, and riverbank protection where possible, particularly in the minor network; substituting the interventions to protect areas of a low intrinsic value (e.g. agricultural and treed areas) with mechanisms for damage compensation.

- **Interventions for recovering geomorphologic equilibrium**

  In the basin: afforestation to stabilize the slopes, monitoring and controlling fires and grazing to reduce erosion, identifying feeder basins for refurnishing the river beds with sediments, eliminating dams and dredging reservoirs (releasing the sediments into the river downstream).

  In agricultural zones: giving incentives for suitable agricultural practices and crops, and regulating land management.

  In the river channel: enhancing the riverbank vegetation, forbidding the extraction of gravel, and limiting the artificial protection of riverbanks from erosion as much as possible, given that the possibility to sediment and erode is key to maintaining the equilibrium of the river channel.

- **Interventions for living with risk**

  Interventions to raise responsibility: informing, sensitizing and educating the public; inducing people to participate in decision-making and assume responsibility.

  Planning the management of emergencies: setting up efficient warning systems for flooding events and appropriate emergency plans; equipping the zones to face these events.[13]

Note that also in this case all these interventions can be decided upon by the administration responsible: a river basin authority, a regional authority, or a local body.

1.1.3 Actions and decisions

Every option for intervention should be then broken down into one or more *actions*, which are characterized by the fact that each one of them can be completely and precisely identified through the specification of the values assumed by a set of attributes (parameters and/or functions). In the 'enchanting lake' example that opens the chapter, the normative intervention can be, for instance, specified by the maximum load [kg/ha/year] of nitrogen allowed in field fertilization, while the construction of the water treatment plant can be defined by its location and by the percentage of nitrogen removed. The *decisions* that the Project must take are concerned with the options for intervention to consider, the type of actions by which

[13] For example, construct buildings on piles; provide openings below flood level with watertight doors; construct retaining walls around buildings; make basements and ground levels floodable without incurring damage; avoid locating residences on the ground floor; provide the sewage system with one way valves; locate the electricity plants, telephone systems and heating above flood level.

to realize them and the values to assign to their attributes. The attributes must be defined in such a way that it is always possible to leave things as they are, i.e. to choose non-action.

As we have already said, an *alternative* is an integrated and coordinated package of actions. The purpose of the Project is to identify the alternative (or alternatives) which permits the achievement of the overall Project Goal among the alternatives being considered. The set of these must always include the *Alternative Zero* (denoted with $A0$), which is composed by non-actions and therefore is often described as *business-as-usual*.

1.1.4 Classifying actions

The actions, and as a consequence the decisions that are concerned with them, can be classified in various ways.

1.1.4.1 Structural and non-structural actions

The first distinction is between *structural actions* and *non-structural actions*: the first are concerned with physical modifications of the system, as, for example, the location and dimensions of the structures for the collection, transportation, distribution and use of the resource. The second either modify the system only functionally or they alter the effects that the system produces. Examples of structural actions are: the construction of a dam or a canal; the installation of an irrigation system; the construction of a waste water treatment plant; and the renaturalization of a river that has been rectified in the past. Examples of non-structural actions are: a regulation that introduces quality standards for effluents; setting tariffs for water services; an incentive programme for farmers to encourage 'virtuous' behaviour (e.g. adopting crops that need less water or planting woody buffer strips); and the regulation policy of a reservoir.

The assignment of an action to one class or the other is not always univocal: for example, the US Army Corps of Engineers classifies the action 'raising a building on piers' as non-structural. The reason is that such an action does not modify the functioning of the system (the river flooding), while it does influence the effects that it produces. Also note that a non-structural action can indirectly produce structural actions. For example, an incentive programme for farmers can encourage them to plant buffer strips along water courses, so modifying the flood regime. Therefore the border between the two classes of actions can be, at times, very elusive, but the classification is useful just the same.

1.1.4.2 Planning and management actions

A second distinction is made between *planning* actions and *management* actions. The discriminating factor is the time step with which the actions are decided. An action is a *planning* action when it is decided once and for all (a typical example is the construction of a dam). An action is a *management* action when it is decided upon frequently or periodically.

There are two outstanding characteristics of management actions. First: when one decides on the next action, up to date information about the system is available so that the evaluations that were carried out to take the previous decision can be updated. Even the decision-making method can be reviewed on the basis of this update. Second: the decision is *recursive* when the system is dynamical.[14] This means that every action will be decided by considering the decisions that will have to be taken in the future on the basis of the

[14] For the precise meaning of this term see Appendix A3.

states that today's decision will have produced. In some ways it is more difficult to choose management actions than planning actions, because it is necessary to evaluate not only the current decision, but also all the decisions that will need to be taken in the future, while taking into account the effects that the first ones will have induced. However, a planning problem can be conceptually more difficult than a management problem, because it may incorporate management problems (think of the Egyptian Water Plan).

We can summarize the twofold classification that has been introduced above with a 'sample' of actions, which is a far from exhaustive list, accompanied by the principal attributes that define them:

- **Planning actions**
  - Structural actions: construction of
    - *Reservoirs*[15]: location, size of the dam, characteristics of the outlets;
    - *Curtains* for pathogenic control or fixing nutrients in natural lakes and reservoirs: location and maximum reachable depth;
    - *Aerators* in natural lakes in anoxic conditions or those requiring destratification: location, depth, power;
    - *Diversions*: location, regulability, maximum derivable flow;
    - *Canals*: location, layout, minimum and maximum flow, presence or absence of coating;
    - *Irrigation systems*: location/extension, irrigation/drainage technique;
    - *Pumping stations*: location, capacity, head;
    - *Aqueducts*: layout, average and maximum flows, losses;
    - *Hydropower plants*: location, intake and outlet points, maximum and minimum flows of the turbines.
  - Non-structural actions: definition of
    - *Management criteria for reservoirs and diversions*:
      - *minimum environmental flow* (MEF), i.e. the minimum flow that must be released to the river downstream from a reservoir whenever the inflow exceeds the MEF[16];
      - storage constraints (regulation range);
      - constraints on the dam operation;
    - *Land use regulations*: zoning, limits to expansion, urban regulation;
    - *Regulation and/or water distribution policies*[17];
    - *Economic instruments*: tariff schemes for water services, insurance plans against the risk of flooding;
    - *Information and education campaigns* to increase awareness: program, people involved, budget, means employed.

- **Management actions**
  - Structural actions
    - *Maintaining storage structures*: volume and location of sediments to be removed in reservoirs and diversion dams;

[15] In the text that follows we will use the term reservoir to refer to both artificial reservoirs and regulated lakes; in other words, we will use it as a synonym for regulated storage facilities.

[16] When the inflow is less than the MEF it is never compulsory to release more than the inflow. This does not exclude that a reservoir could be used for low-flow augmentation.

[17] See page 40.

    - *Planting woods*: number, type of plants, and frequency and zones of afforestation.
  - Non-structural actions
    - *Releasing water from reservoirs*: flow rate;
    - *Aerating natural lakes and reservoirs*: intensity;
    - *Operating curtains*: depth;
    - *Reviewing economic tools* in the light of contingent conditions: degree of variation;
    - *Broadcasting alarms and pre-alarms for floods*: area involved.

Note finally that another attribute, which must be considered for all these actions, is the time at which its effects will come about: for example, the time a dam becomes operational or the time a regulation comes into action. This attribute is of particular interest not only for Programs, but also for Projects, when short-term (transient) effects are considered (see Section 3.2.2.1).

1.1.4.3 Other classification criteria

Another classification criterion is based on the aim of the actions. This is how we have classified the actions in the two examples that open this paragraph. A further possibility is to classify the actions according to the Decision Maker (DM) that can take them, or according to the decision-making level at which they are established. For example, a public administrator, a single farmer and an individual citizen all operate at different levels: the first can decide on all the actions listed in Section 1.1.1, the second only on crop rotation, irrigation techniques and agricultural practices, while the third decides how to save water when brushing his teeth or taking a shower.

1.2 Difficulties and keys to their solutions

The projects that we are concerned with show two fundamental characteristics: they involve many individuals (even sometimes many DMs), and they require a decision from an Agency or a public body (the choice of the alternative to be implemented or simply the authorization to implement an alternative proposed by others). For this reason we talk about decisions in the public realm. Such decisions are usually taken by following the procedure described in the diagram in Figure 1.3. In the diagram the term *Decision Maker* (DM) refers both to the commissioner of the Project, who oversees the first phases (e.g. the Egyptian Ministry of Public Works that wants to produce the Water Plan), and the final DM, who must approve it (in the example the Government or Parliament). The *Analyst* is (s)he who actually conducts the necessary studies and draws up the Project on paper. It can be a technical office of the same administration, but, more often, it is a consultancy that has been entrusted with the job after putting in a tender. The *Stakeholders*[18] are either all those (people, institutions, organizations) that experience the effects of the Impacts for which a Response[19] is being sought, or those that could be influenced by the options for interventions considered for implementing the Response. The horizontal arrows indicate the moments in which the *actors* (DMs, Analyst, and Stakeholders) interact and their direction leads from those that pose the questions to those that must respond.

[18] Some prefer to call them 'rightholders', which is a broader category, according to those who support the idea, than Stakeholders. In actual fact, however, often there are Stakeholders whose rights are not recognized.

[19] According to the terminology of DPSIR scheme in Figure 1.1.

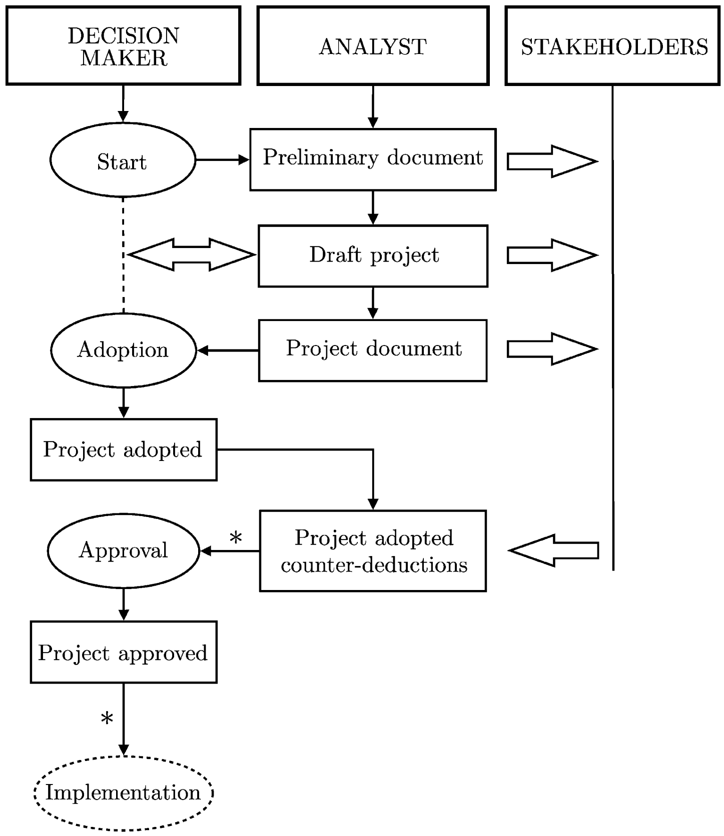

Figure 1.3: The standard procedure for a planning process.

Often the two steps that are indicated with an asterisk are protracted for an excessive amount of time, sometimes even for years, and, since they are not transparent, it is not always very clear what is happening. Informal negotiations, lobbying and political battles are likely to develop. There are two principal difficulties that provoke these delays:

- the *conflicting interests*[20] are often of great importance, especially economic importance and when not adequately managed, can lead to lobbying, opposition and boycotts;
- the *inadequacy of the approach* that is top–down, i.e. a Decision–Announcement–Defence approach. The administration decides, communicates the decision and defends it from the Stakeholders' reactions; the latter, having had very little influence on the decision, are almost always against it. Furthermore, the approach emphasizes the political component of the decision, which while it is certainly essential for orienting the evolution of the system in the long-term, by its nature does not provide the

[20]"Perceived divergence of interests, or belief that the Parties' current aspirations cannot be achieved simultaneously" (Rubin et al., 1994).

transparency, the credibility and the explanation of the choices that the Stakeholders demand. In addition, it risks being technically inefficient and unsustainable because the information-modelling and decision-support tools that are available today are too often not really integrated into the approach, but only juxtaposed, at times, acting purely as frills.

In order to achieve good planning and good management it is absolutely necessary to overcome these difficulties by conducting a *participatory, integrated and rational decision-making process*. Let us examine these three adjectives one by one.

1.2.1 Participation

1.2.1.1 Awareness

If we do not manage to awaken or instill profound human values, such as a sense of belonging to the territory, a love for the environment, and a responsibility for its evolution, we will not be able to get very far. Therefore, education is fundamental and must be structured at many levels, from children to administrators and politicians, including technicians and the general public. In this book we will not linger over the ways to increase awareness of the problems, especially environmental ones, but that does not mean that this issue can be neglected.

1.2.1.2 The participatory process

The top–down approach of the standard planning procedure needs to be reversed, proposing and launching a participatory process (Renn et al., 1993; Renn, 1995; Budge, 1996; Delli Priscoli, 2004), that is 'bottom–up' and based on the management of participation: a process of participation that begins from the proposal of the Project, the recognition of the need for the process itself, and continues with the choice of the alternative to be implemented, right through to the monitoring of the effects after its implementation. This process should not be limited to providing the Stakeholders with information (*Informative Participation*), nor to just asking them for information (*Consultation*), but should also involve the Stakeholders in the design and evaluation of the alternatives (*Co-designing*) and ideally even in the final choice (*Co-deciding*)[21] (Mostert, 2003; Hare et al., 2003).

In this way, a process of *social learning* is created, in which the Stakeholders become aware of the problem, of the alternatives, and of the viewpoints of others; they take responsibility and together they develop the alternative to be carried out (Renn, 1995). The key ingredients are information, transparency, repeatability, and the active involvement of the Stakeholders. In order for the process to be effective, it must be supported by an open and flexible decision-making procedure to accommodate the unforeseen events and elements that are introduced by the Stakeholders. At the same time this process must be structured, so that it does not degenerate into a 'condominium meeting' (see Renn et al., 1995, for an

[21] With surprising speed legislation has already adapted to this need: the Århus Convention, signed in 1998 and in force since 2001, recognizes citizens' rights to "have access to information and be enabled to participate in the decision-making process with regard to the environment", based on the principle that only participation can make sustainable development possible. In escort to that convention, the Directive 2003/35/EC (European Commission, 2003b) was issued by the European Parliament which establishes that "the public concerned shall be given early and effective opportunities to participate in the environmental decision making procedures" right from the initial phases, so that they have an effective possibility to influence the choices. The Water Framework Directive (WFD) [Directive/2000/60/EC (European Commission, 2000)] anticipated this position.

evaluation of different approaches to participation). As it will be shown in Section 1.3, the synthesis between these antithetic characters can be achieved with an accurate, explicit and shared definition of the phases of the process and professional guidance of the moments in which the interaction and negotiation between Stakeholders take place.

A participatory process takes time and it is this aspect in particular that often discourages its implementation. The final goal should be made clear: if it is the ‘actual implementation of Responses’, then a participatory process is almost always quicker and more efficient than a non-participatory one (the duration is measured between the beginning of the Project and the end of the implementation phase). If, instead, the goal is just to ‘draft the Project’, then the non-participatory process is faster, because it avoids many tiring phases of negotiations (in this case the duration is measured from the beginning to the approval of the Project). However, drawing up a Project which almost surely will not be implemented because it is not shared, is a real waste of public money.

Here are some *guidelines* to stick to when developing a participatory process:

1. Share the idea that everyone is working together to solve a problem and improve the quality of life.

2. Participation, not just communication: accept that the participation really influences the final decisions.

3. Always stick to what was agreed upon in the previous meetings.

4. Create responsibility through agreement.

5. Try to transform the difficulties into opportunities,[22] for example, looking for alternatives so that no one is, if possible, worse-off than before[23] (*win–win alternatives*).

6. Look for equity by identifying who bears the costs and who reaps the benefits; look for interventions that make those that impose costs on others responsible for their actions.[24]

7. Guarantee flexibility, but maintain rigor, to avoid ‘houses of cards’. One should not proceed by taking decisions on a weak basis that can crumble afterwards. A well conducted process gains the confidence of Stakeholders, who will then be under pressure to participate for fear of being excluded from decision-making.

8. Look for agreement at every step, but at the same time accept that differences and uncertainty are integral and inevitable parts of the process. Do not force the Parties to rush at an agreement, but accept that, in order to reach one, time and interaction are required.

[22] Often it is only a matter of imagination: if for example a group of farmers are opposed to a project for a river park because they fear that they will have to change their activities and be dispossessed of their land, the opposition could be overcome by also including among the actions of the Project, to be developed with those same farmers, a reconversion action of cropping patterns: e.g., substituting the production of maize with biological crops or high value herbs that can be cultivated and certified, thanks to the very fact that the park exists. For this reason, also interventions for training and technical assistance have to be considered in the project, and potentially subsidies. Furthermore, instead of expropriating the lands, one can think about a form of contract to use land for reciprocal advantage.

[23] Excluding, clearly, those that started in an illegal condition.

[24] For example, by imposing a tax on dumping polluted waste.

9. Provide guarantees instead of demonstrations. It is useless to insist that there will not be undesirable effects; it is much more convincing to sign a commitment to a corrective action in the eventuality that the effects that the Stakeholders fear do occur.

10. Recognize that the public has a role to play in monitoring and carrying out the project.

11. Accept the existence of different points of view.

12. Distinguish facts from value judgements, which are the product of subjective preferences.

13. Keep the decision-making process transparent and repeatable, guaranteeing access to information.

14. Respect the role of the political DM, but make sure that she explicitly clarifies the reasons for her choices.

And here are a few *sine qua non* conditions that the Analyst must respect, if the participatory process is to be successful:

1. State the criteria and the rules to follow and respect them. The 'statute of participation' (Connor, 1997) is a useful tool: it is a document that states principles, intentions and rules of the decision-making process.

2. Define the decision space clearly, and clarify the 'power of the participation machine' and the relations with the Administration.

3. Have the DM participate in the meetings with the Stakeholders, ideally in person, or at least by sending a delegate.

4. Act in a way that gains the trust of all the Parties and never betrays that trust.

5. Be very careful to uncover any misunderstandings that are produced by the terminology and have the patience to take the time and energy to resolve them.

6. Evaluate often the state of the participatory process.

1.2.1.3 Evaluation for negotiations

It is almost always impossible to identify an alternative that produces the best possible effects for all the Stakeholders. Each alternative is a particular compromise between the interests[25] at stake and thus it is essential that its effects be evaluated from the viewpoint of each Stakeholder, so that each one can express his/her opinion about it and negotiate the *best compromise*.

1.2.2 Integration

The decision-making process must be founded in the *principle of integration*, which manifests itself at many levels:

[25] By the term *interest* we mean the needs, desires, worries and fears, concerns, and more generally, whatever reason that encourages a Party to negotiate.

- among the parts that compose the system;
- between rationality and emotionality;
- among Stakeholders and political DMs;
- among the Stakeholders themselves, particularly between those who benefit and those who incur damage;
- among the evaluation approaches: Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), Multi-Attribute Value Theory (MAVT), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA);
- between environmental policies and sectorial policies (applying the *precautionary principle*[26]);
- between technical approaches to solution and decision-making techniques (*integrated technical approach*);
- between planning and implementation (plan/project; SEA/EIA) and between strategic and tactical scales (applying the *subsidiarity principle*[27]).

In our view, the keys to integration are the correct identification of impacts and the correct identification of the indicators that quantify them, and so two conditions must be respected:

(a) the Stakeholders whose interests will be, or might be, affected must be clearly identified: not only those who could be disadvantaged by the decisions being considered, but also those who may benefit;

(b) the values that the Stakeholders attribute to the impacts must be made explicit (Keeney, 1992).

In this way, the evaluation can focus on the reasons why an alternative is preferable to another, rather than fall into a sterile conflict of positions, in which some defend an alternative to the utmost while others attack it.

1.2.3 Rationalization

We have therefore understood that the decision-making process must be rationalized through the adoption of a precise *decision-making procedure* that allows the *best compromise alternative* to be identified. This is done by way of a participatory negotiation process that is structured and transparent, and whose core is an integrated evaluation that allows each Stakeholder to evaluate the effects that will result from each alternative, and explicate the political compromise between conflicting interests upon which every choice that is made is founded.

[26] Environmental phenomena are very complex and in many cases we do not know how to predict their effects, especially in the long-term. It is therefore advisable not to take actions whose effects we are unable to evaluate or, if it is really necessary to take such actions, to do so only with appropriate security measures.

[27] To each administrative level (e.g., Ministry of the Environment), leave only the decisions that cannot be taken at a lower level (e.g., Province) so that procedures are quicker and more responsibility is given to the lower levels.

The first, fundamental condition to identify an alternative that enjoys a wide agreement is that the very decision-making process get the consent of the Stakeholders. To this aim the sought-for procedure must:

- break the process down into phases and establish the sequence in which they are executed; and
- specify the aim of each phase and the technical means (algorithms and procedures) by which it will be achieved.

In addition, it must give a concrete form to principles 11–14 stated above. More specifically:

- accepting different points of view translates into the fact that each phase (except for the last) can close with a plurality of outputs, all equally adequate;
- maintaining the distinction between facts and value judgements does not mean that subjective preferences are suppressed, because they too guide the choices, but that they are kept distinct from that which is 'objective';
- the transparency and repeatability are realized by making the information available to all the Stakeholders and the DMs, documenting and distributing the results of all the phases;
- and lastly, respecting the role of the final DM means that the final choice (and therefore the last phase of the procedure) is reserved for her and she is guaranteed the right not to choose one of the alternatives that have emerged from the decision-making process. However, the procedure must ask her to justify the choice with the same instruments (indicators and criteria) that were defined by the Stakeholders during the course of the process. If the process was well conducted, the DM's different choices should be justified only by the different relative importance she gave to the evaluation criteria.

The definition of the decision-making procedure is the subject of the next section.

1.3 Planning: the PIP procedure

Sometimes there is more than one DM, as would be the case if the 'enchanting lake', in the example that opens this chapter, and its inlet were to define the border between two countries. In that case, neither of the DMs (the Environmental Agencies of the two countries) could assume efficient decisions autonomously. Even when only one DM is concerned, we have seen (Section 1.2.1.2) that it is advisable to choose the best compromise alternative by taking into account the Stakeholders' viewpoints. For this reason, the decision-making procedure should not be limited to considering information collected from the Stakeholders (*Consultation*), but they should, instead, be treated as if they were DMs that must negotiate a compromise alternative (*Co-deciding*). The goal of the decision-making process is to reach an agreement that is acceptable to them all, to which they remain committed, and which is actually implemented. Only the last, decisive step of the procedure (the formal choice of the alternative that is to be implemented) is in most cases the reserved responsibility of the DM (or DMs) that has (have) the institutional power and responsibility to make the choice.

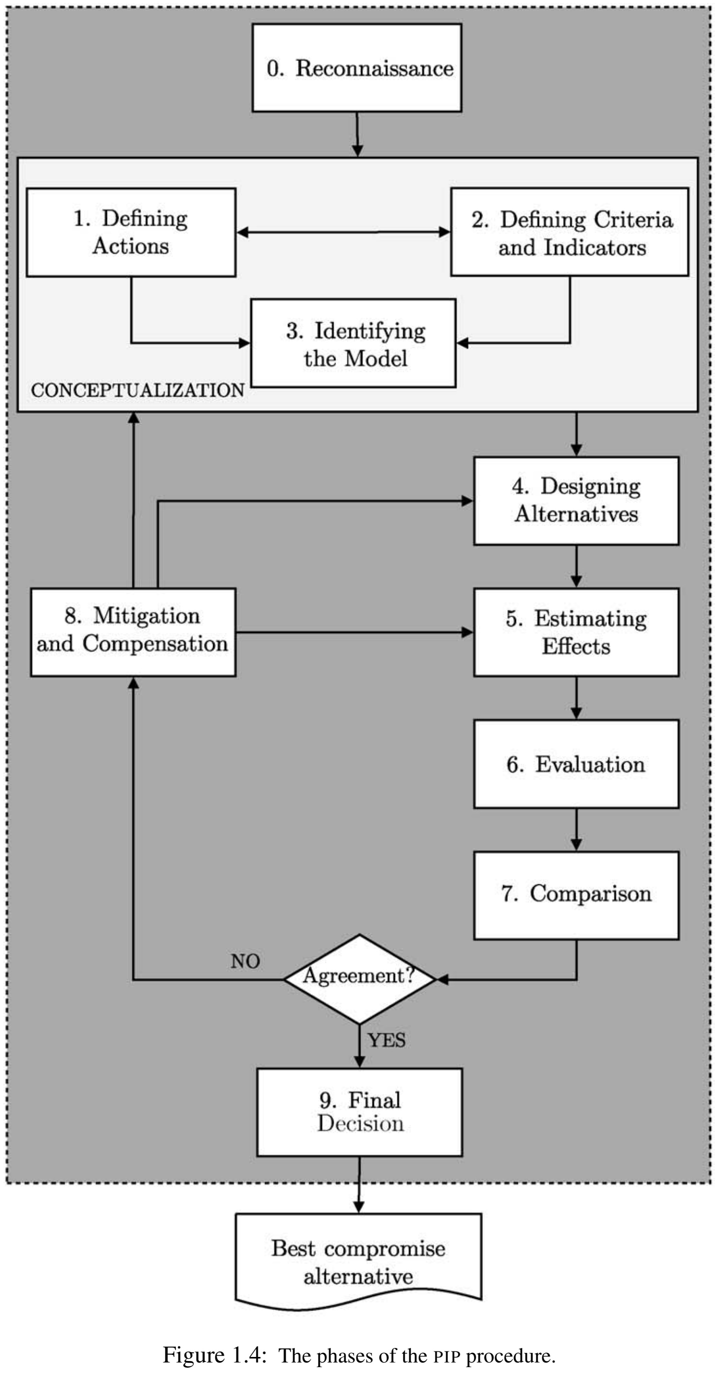

Figure 1.4: The phases of the PIP procedure.

In Figure 1.4 the flow diagram of the procedure that we are proposing is shown. We call it PIP procedure, for Participatory and Integrated Planning procedure.[28] The diagram is also a conceptual map of the modules of the software systems used to implement the decision-making procedure, called *Multiple Objective Decision Support Systems* (MODSS). This structure is also reflected in the succession of the parts and of the chapters in this book. The description of the component phases is only a preview of what will be presented in detail in the following chapters. Many new concepts appear in it and some may, inevitably, seem obscure. If this is so, the reader should not be discouraged, because such doubts are completely normal and will be dispelled further on. What we wish him/her to capture is just a view of the whole procedure. Keep in mind that all the terms in italics will be picked up and carefully defined in the following chapters. This paragraph can be seen both as the beginning point and the conclusion of the book. When the reader has completed the book, our advice is to read it again. If at that point the contents seem evident and meaningful it will mean that our efforts have been successful.

1.3.1 The phases

Phase 0 – Reconnaissance

Statisticians consider two types of errors: type I error (rejecting a true hypothesis) and type II errors (accepting a false hypothesis). The aim of *Reconnaissance* phase is to avoid "type III errors": solving the wrong problem (Raiffa et al., 2002). The work is concentrated on defining the *Project Goal*, the (spatial and temporal) boundaries of the system being considered,[29] the normative and planning context in which the procedure operates, the data available, and the information that needs to be collected.

One must start off from the identification of the Stakeholders involved and their needs, expectations, fears and perceptions, in a word, their *interests*.[30] In fact, the definition of the Project Goal closely depends on the interests being considered and on the hopes and expectations that one wants to fulfil.

Then the PIP procedure has to be explained to and accepted by, or, if necessary, negotiated among all the actors (Stakeholders and DMs).

At this point it becomes possible to define the *Goal* that the Project must pursue. It is derived from the DM's strategic goals, from the Stakeholders' interests and from the regulatory and planning context. In the case of the Egyptian Water Plan the specific Goal of the Plan ('to improve the quality of life for Egyptians by targeting water availability') was derived from the government's strategic goal 'to improve the quality of life for Egyptians'. It is useful to translate the Goal for each Stakeholder into a *vision* that visualizes, with words, or better still, with a picture, the condition that the Project aims for. For example, the vision for the civil users of the Egyptian Water Plan could be: "no longer water only in the evening from 17:00 to 20:00 one day in three, but a continuous reliable supply, which is not too expensive . . . "; while a project for upgrading a river system could be expressed by the pictures in Figure 1.5. The choice of a good vision is important

[28] Even though it was devised autonomously, it can be interpreted as a variation of the PROACT scheme proposed by Hammond et al. (1999), which has been suitably modified to take into account that, in the case we here examine, the decision-making process is targeted at consensus building and actions include management, i.e. recursive decisions.

[29] These two points are often referred to as *scoping*.

[30] "It is crucial for the legitimacy of a planning process to start dialogue as early as possible in the phase of problem definition" (European Commission, 2003b).

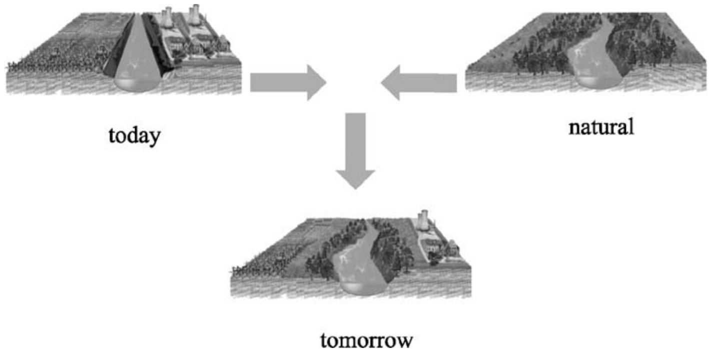

Figure 1.5: The *vision* of a river upgrade project (from CIRF, 2004).

when the Stakeholders are not very motivated to take part in the decision-making process or resistant, or unable to express their own goals.

An extensive knowledge of the system is the fundamental support to all these activities and it is acquired by: analysing the regulatory and planning context of the Project; collecting the information and data available; identifying the missing information; and finally, filling the information gaps by conducting hydrological, economic and social surveys. The actors should share all the available information, agree upon its validity (this is crucial!) and the potential need for further investigations. In other words, when necessary, even the validity and availability of the information must be negotiated.

An example of Phase 0 is presented in Chapter 2 of PRACTICE.

Phase 1 – Defining Actions

In this phase, the options for intervention that are supposed to achieve the Project Goal must be identified, bearing in mind the interests of the different Stakeholders. This is not a simple operation because the opinions can be very discordant. For example, for some the obvious solution for the 'high water' problem in Venice would be the construction of the MOSE[31] at the mouths of the lagoon, for others it is the construction of gate-ships,[32] which are less complicated to construct and which would be more adaptable to the bradyseism of the lagoon bottom; others say that the only sensible option would be the reduction in the green house gas emissions that are responsible for the eustatic sea[33] in front of the lagoon. From this initial, decidedly disorganized, collection of ideas, which are in part silly, in part gifted with incredible wisdom, good ones always emerge. It may

[31] A system of submerged hollow steel gates, hinged at the bottom of the lagoon and installed at each of the lagoon's three openings to the Adriatic sea. When 'high water' is foreseen, they can be raised by pumping compressed air into them and creating a sea barrier.

[32] Two ships, whose length is about half the width of the mouth of the lagoon, which are hinged to the two offshore piers that mark the mouth's boundaries. The free end of each ship is equipped with a propeller that allows them to position themselves across the mouth opening. When the ships are in this position they flood the compartments that make up their hulls so that they sink, creating an insurmountable barrier for the sea. When the high water event is over, the mouth of the lagoon is reopened by reversing the operation. The major advantage with respect to the MOSE is that the construction and the maintenance are done on dry land and the mouth of the lagoon would need to be modified only slightly.

[33] The phenomenon of sea level rise in the long-term in response to geological and climatic changes, such as, for example, the melting of the polar ice caps, produced by the green house effect.

seem strange to begin with brain storming; however, it is essential to promote creative decision-making that considers more than just a set of interventions given a priori, and is able to open new perspectives and discover unexpected alternatives. If an intervention is really useful it will emerge in the following steps, and if all the Stakeholders' suggestions are considered and processed, they are more prone to collaborate since they feel they are being "taken seriously" (WFD, Annex VII, point A9, see European Commission, 2000). Moreover, how can there be a participatory process if one does not listen carefully to the ideas and proposals of the actors?

This first, creative phase must necessarily be followed by a phase of 'sedimentation', in which we separate what can be decided and what cannot, and thus, the effective decision space becomes apparent. It is in fact useless passionately to debate aspects that cannot be decided in the Project. But note carefully that this is not the time to discriminate the useful interventions from the useless ones, or the sensible ones from the less sensible. This will be a task for the next phases. Here, we only aim at obtaining a list of the interventions 'that can be decided upon' in the context of the Project, e.g. in the case of the Egyptian Water Plan one obtains an extract from the long list of actions in Section 1.1.1.

Each intervention is finally broken down into one or more (*meta-*)*actions*, i.e. into elementary interventions that can be fully and easily defined by specifying the values of their attributes (see Section 1.1.3), that is by specifying who is doing what, how and when. In this way a meta-action is transformed in an *instantiated* action. Technically, this transformation is carried out by assigning values to the parameters and/or the functions that describe the attributes of the meta-action. The specification of these values is a matter for a future phase (Phase 4: *Designing Alternatives*), but their feasibility sets have to be defined in this phase, thus fixing the meta-actions to be considered. The instantiated actions are the 'building blocks' from which the alternatives will be constructed later. In the following, as we have done so far, we will use the term 'action' to denote both the meta-actions and the instantiated actions. The actual meaning will be clear from the context.

A complete example of this phase is described in Chapters 3 and 5 of PRACTICE.

Phase 2 – Defining Criteria and Indicators

To evaluate and compare the effects of the alternatives on the system it is necessary to identify, together with the Stakeholders, a set of *evaluation criteria* that reflect the characteristics of the problem and the values that are at the base of the judgements that the Stakeholders express. The criteria do not have to pertain only to the Project Goal, but to all the positive and negative effects that the Stakeholders hope for or fear: in other words they must express their interests.[34] In particular, the criteria for sustainable development will be proposed by the Agencies and by the Environmental Associations which must always be included in the Stakeholder group.

Not every evaluation criterion is necessarily expressed in an operative way, i.e. it may not spontaneously define a procedure that allows us to ascertain how much a given alternative satisfies that criterion. This is why an *index* must be defined, that is a *procedure* which associates the criterion with a value expressing its satisfaction (see Chapter 3). This is done through the identification of relationships between the evaluation criterion and the

[34] Objectives are the same as interest: unfortunately the negotiation theorists and the decision-making theorists have not agreed on a common term. The first talk about 'interests' and the second about 'criteria and objectives'; but they mean the same thing. We will adopt the jargon of the second group.

variables (e.g. lake level and water release, river and channel flows) that describe the system condition. In practice, one proceeds by first splitting the evaluation criterion into lower level criteria and, in turn, splitting those into even lower level criteria, until it is possible to associate each one of the criteria at the lowest level (*leaf criteria*) with an *indicator*, i.e. a function of the trajectories of the variables describing the system condition. In this way a hierarchy of criteria is obtained for each evaluation criterion. The definition of a criterion and of its hierarchy ought to encompass either thresholds (e.g. minimum environmental flow or the level above which a flood occurs) or a Stakeholder's wish (*leitbild*, see Egger et al., 2003), which is often related to the performance level (s)he demands (e.g. a preferred flow).

It is necessary to dedicate a great deal of time and attention to interactions with the Stakeholders and to studying their points of view, because it is essential that each Stakeholder sees that his/her interests are expressed in at least one of the indicators. If this does not happen, negotiations in Phase 7 will inevitably fail.

In the next phase we will see that very often the system is affected by *random inputs* (either *stochastic* or *uncertain*). It follows that also the values assumed by the indicators are not generally deterministic. When this occurs, it is necessary to take account of the *risk aversion* that the DMs and Stakeholders may have. This can be expressed through the classical approach of utility functions, proposed by Keeney and Raiffa (1976), but more often it is translated through *criteria*[35] from which the most frequently adopted are the *Laplace criterion* (expected value) and the *Wald criterion* (worst case) (French, 1988). We will deal with these in Chapter 9.

Like all the phases of the PIP procedure this one must also be participatory: the evaluation criteria should be forthcoming from the Stakeholders and the definition of the indicators must have their contribution and approval. This last step is, however, often very technical and so, as for the technical steps in the following phases, the Stakeholders can be supported by *Experts*.

Phase 3 – Identifying the Model

In order to quantify the effects that the different alternatives would produce on the different indicators if they were to be implemented, it is necessary to provide a *model* that describes the cause–effect relationships within the system. Such a model can take the form of an Expert, who, on the basis of his experience, is able to estimate the effects that each alternative will produce (see for instance the MÖLL Project (Muhar and Schwarz, 2000; Jungwirth et al., 2000)). Alternatively, it can take the form of a mathematical model, which is the type of model considered for the most part in this book. The choice of the level of detail in which the model must describe the phenomena is strictly connected to the indicators defined in Phase 2 and to the actions that are considered. In the case of the 'enchanting lake' described in the introduction, the regulations could be planned by describing the system by a set of algebraic equations, while an executive project for artificial aeration would require the system to be described by differential equations.

The input variables of the model must include the parameters that quantify the attributes of the actions (e.g. the maximum nitrogen supply allowed in agricultural practices and

[35]Take care not to confuse this meaning of the term criterion (Stakeholders' attitude towards risk, see Section 9.1), with the one previously introduced (judgement category). We will encounter semantic ambiguities of this type on other occasions: they occur when the subject of discourse is on the frontier of different disciplines, each of which has independently developed its own jargon.

the nitrogen removal efficiency of the treatment plant) as well as all the variables that allow the future conditions of the system to be described (e.g. the precipitation in the catchment area and the users' water demand). The choice of values to attribute to the former constitutes the subject of the Project, while the values assigned to the latter describe the context within which the alternatives are evaluated and are therefore called the *scenario*.[36] Both alternatives and scenarios have to be quantitatively specified before the model can be run. Note that there can be more than one scenario: in the 'enchanting lake' example we might be interested in evaluating what would occur in a 'high' or in a 'low' rainfall scenario. Moreover, the scenario is not compulsorily deterministic: very often it can be random.

The scenario(s) may be chosen by Experts or it (they) can be obtained by running models, if they are available, that describe the processes that produce the driving forces. In the 'enchanting lake' example the future scenario of rainfall can be generated by a climate change model, while the future scenario of agricultural practices can be suggested by an Expert. When all the processes are stationary, the *historical scenario*, i.e. the trajectories registered in the past, is often adopted for the reasons that will become apparent in Phase 5. In any case, the time horizon of the scenario should be sufficiently long to capture all the types of significant events the system may face. It is a common practice to adopt different scenarios for the design of the alternatives (*design scenario*) and for the estimate of the effects (*evaluation scenario*, sometimes also called *baseline scenario* (BLS), see Appendix A1), which are generally fixed in the corresponding phases.

To facilitate a *social learning* process and help the Stakeholders share a quantitative understanding of the system it is important that they go through the same thinking process and be exposed to the same information and arguments as the Analyst. For this reason, the implicit assumptions of the models should be made explicit and the modelling activity should be supported by an MODSS that must be flexible enough to identify models through a participatory process. Only in that way can the Stakeholders share a common interpretation of the system behaviour (model), which is necessary for them to be able to trust the effects that are estimated with the model. Agreeing on the same model does not prevent them from having different perceptions (indicators) of these effects.

We will deal with these issues in Chapters 4–6.

The set of Phases 1–3 constitutes the *conceptualization* of the Project.

Phase 4 – Designing Alternatives

Unfortunately, very often, it is common practice to consider only the alternatives that are prompted by the Analyst's experience and the suggestions from the Stakeholders. These alternatives make a good starting point, but we believe that it would be a mistake to limit the choice to them alone. More correctly, remembering that an alternative is an integrated package of actions, all the alternatives that can be obtained by combining the actions identified in Phase 1 in all possible ways should be considered. Often the number of alternatives that follows is so high that it would be impossible to examine them all in the following phases and so it is necessary to select only the 'most interesting' ones.

[36] Dictionaries give the term scenario the following definition: "a possible set of future events". Brought into our context the term lends itself to three different possible meanings: (1) synonymous to alternative (e.g. *business-as-usual scenario* means *Alternative Zero*); (2) the set of effects that an alternative produces; (3) the time series of input variables that are not controlled by the DM. We will strictly adhere to this last meaning.

However, these must be chosen still following the Stakeholders' criteria, which were identified in Phase 2, rather than the Analyst's preferences.

In more complicated projects, such as those that this text is concerned with, where a higher level of mathematical formalization is required, to identify the 'most interesting' alternatives it is necessary to define a mathematical problem (a Mathematical Programming Problem or an Optimal Control Problem), called *Design Problem*, which selects the *efficient alternatives* with respect to *objectives*, accordingly called *design objectives*. These are defined on a *design horizon*, given the *design scenario* and taking into account only a subset of the evaluation indicators: the *design indicators*. This simplification is introduced when the considering of all the evaluation indicators would make the Design Problem unsolvable in acceptable computing times; it does not excessively polarize the result if the design indicators are carefully chosen, since in Phases 5 and 6 the alternatives will be evaluated with respect to the complete set of indicators.

The characteristics of the system appear in the Design Problem as *constraints*, while other elements that define the design scenario (e.g. user demands, produce prices) contribute, along with the structural and normative actions, to determine the value of parameters that appear in the constraints and in the objectives of the Problem. Solving the Problem through an appropriate *algorithm*, provides the set of alternatives that will be examined in successive phases. To these the *Alternative Zero* ($A0$) is always added, that is the alternative that assumes that nothing is done and everything remains the way it is (business as usual).

Chapters 7–18 are dedicated to the definition of the Design Problem and to the study of the algorithms that solve it.

Phase 5 – Estimating Effects

Once the alternatives have been identified, the *effects* that each produces must be estimated: in other words, it is necessary to compute the values that the indicators assume as a result of each of the alternatives being implemented. When the system is not dynamical, the evaluation is immediate. When the system is dynamical this estimation requires that each alternative be simulated over a time horizon (*evaluation horizon*) long enough to make extreme events (e.g. droughts or floods) likely to occur, in order to avoid the risk of estimating the effects in 'average conditions' only. In both cases it is necessary to feed the model with an appropriate input: the actions of the alternative considered and one or more *evaluation scenarios*. The alternatives will be compared to single out the 'best' one on the basis of the effects estimated in correspondence with one of these scenarios, the most probable for example; the effects estimated with the others will be useful for evaluating what would happen if the scenario did not occur and in order to adopt a precautionary viewpoint. The choice of the scenario(s) to adopt can be critical, and all DMs and Stakeholders must agree, otherwise, the following phases would fail.

The adoption of an *historical scenario* (i.e. of a situation that was historically recorded) has an advantage in that it allows the comparison between what happened and what would have happened if the alternative had been implemented at the beginning of the historical horizon being considered. This information has a heightened significance for the Stakeholders and DMs because it provides a more immediate perception of the effects of a given alternative, when they have, as they often do, a direct memory of those events. If the historical horizon is too short, artificially generated scenarios can be used, provided that they are as probable as the historical one. By doing so, the estimate of the effects is statistically more reliable, but the psychological significance is lost. Both of these ways to proceed are meaningful only when one can reasonably assume that the processes that generate the scenario (e.g. the meteorological system and land use) remain unchanged into the future. If not, the scenarios have to be generated with models that describe the expected changes.

At the end of this phase the values that have been obtained for the indicators are organized in a matrix, called *Matrix of the Effects*, whose columns correspond to the alternatives and whose rows to the indicators.

In Chapter 19 we will describe these issues in detail.

Phase 6 – Evaluation

An indicator measures, in physical units, the effect produced by an alternative on a particular leaf criterion (see page 23). Nevertheless, the 'value' that the Stakeholders attribute to an alternative, in other words the satisfaction that they get from it, is not always directly proportional to the value assumed by the *evaluation indicator*. In the 'enchanting lake' example, the 'value' that the fishermen attribute to the catch grows very rapidly for low catch yield, but very slowly at high catch yield, i.e. it 'saturates' when the fishermen feel satisfied. To account for this effect, it is necessary to translate each indicator (sometimes a group of indicators) into the 'value' assigned by the Stakeholders. This can be done by means of a *partial value function* that has to be identified through interviews with the Stakeholders. Once all the indicators are transformed into 'values', a Stakeholder (or a DM) can express the overall satisfaction that (s)he assigns to an alternative through a dimensionless *index*, whose value can be computed from the attained 'values'. Therefore, it is possible to sort the alternatives by decreasing values of the index, thus identifying the alternative that the Stakeholder (or the DM) prefers (the first alternative in the ranking).

If there is only one Stakeholder (or DM), the *optimal alternative* is found and the decision-making process is concluded. We will study this in detail in Chapter 20.

When, instead, as is almost always the case, there is more than one Stakeholder (or DM), by working in the aforesaid manner a different ranking is obtained for each one of them. The choice of an alternative then requires the expression of a judgement about the relative importance of the involved Parties (Stakeholders or DMs), i.e. requires that the Parties negotiate between themselves or that a DM (or a Super-DM) expresses her preferences among the Parties (Stakeholders or DMs). Since, however, preferences and negotiations concern subjective aspects, dealing with them is postponed to the successive phases to maintain the distinction between facts and value judgements, as required by guideline 12 in Section 1.2.1.2.

Phase 7 – Comparison

The aim of this phase is the identification of an alternative that is judged to be an *acceptable compromise* by all the Parties and so does not encounter opposition from anyone. Clearly a *win–win* alternative, i.e. an alternative that improves all the Parties' indices with respect to the Alternative Zero, would be the ideal solution for the decision-making process. Unfortunately, such an alternative does not always exist. In a case of irresolvable conflict between the interests of different Parties, the phase concludes with the identification of the alternatives that obtain wide *agreement* from them and listing the supporting and opposing Parties for each of them. We call these alternatives *reasonable alterna-*

tives[37] (or *compromise alternatives*[38]). Thus, with this term we refer to the alternatives that are supported by at least one Party, are admissible (because they satisfy physical, technical and legal constraints), are economically feasible and are Pareto-efficient, i.e. they are such that it is impossible to improve the satisfaction of one Party without worsening that of another (see Section 18.2).

To achieve this result, first of all a series of activities is promoted, which help each of the Parties to know and understand the others' points of view, and, if such exist, the negative effects that the alternative (s)he prefers produce for the others. Once this information has been shared, the heart of the phase is the search for a compromise through *negotiations* among the Parties.

The negotiation process can take place with different procedures that we will study in Chapter 21. Sometimes it is necessary to suspend negotiations and move back to Phase 4 to design other alternatives, in view of what has been understood of the needs, aspirations and requests of the Parties; the effects of the new alternatives should be then estimated (Phase 5), evaluated (6) and brought to negotiations (7). In this way an iteration between Phases 4–5–6–7 is established; an example of this can be found in Sections 5.4 and 10.5 of PRACTICE.

Phase 8 – Mitigation and Compensation

If an alternative enjoys the agreement of the majority of the Parties, but not all them, it is important to explore whether or not it is possible to enlarge the agreement and satisfy some of the unsatisfied Parties through *measures* (meta-actions) of mitigation or compensation. To do this it is necessary to identify new (meta-)actions to include in the alternative, which act specifically on the criteria of unsatisfied Parties. Once these (meta-)actions have been identified, they must be instantiated into actions (Phase 4) and their effects estimated (5); then they must be evaluated (6) and compared (7) with the reasonable alternatives previously identified, in order to see if they actually broad the agreement. In this way one obtains a new set of reasonable alternatives, which could be examined in their turn to find new mitigation measures. Mitigation will be analysed in Chapter 22.

Here a recursion is established between Phases 4–5–6–7–8 (Figure 1.4), which sometimes also includes Phases 1–2–3, during which the whole set of alternatives is 'sifted' in order to single out the reasonable alternatives. Sifting ends when a reasonable alternative is identified, which is accepted by all Parties; or when it is no longer possible to identify mitigation measures or new measures that make it possible to enlarge the agreement; or simply when the time available for the decision-making process has run out. By construction, each alternative obtained in this way has the support of at least one of the Parties. All of them are presented in the summary document of the study (see for example Chapter 15 of PRACTICE), which sums up the entire development of the Project and its results. This document is the material needed to begin the next and last phase.

[37] This term is taken from art. 5 of the Directive 2001/42/EC (European Commission, 2001) about Strategic Environmental Assessment (SEA).

[38] They are given this name because they emerge from a process of negotiation in which an attempt is made to find a compromise among different points of view. However, it is not necessarily possible to achieve this, so the term seems equivocal to us and we prefer the first.

Phase 9 – Final Decision

This phase is put into practice only when there are one or more DMs, at a higher level than the Parties who sifted the alternatives, who are responsible for the final decision about which alternative will be implemented. It is therefore up to these DMs to choose the *best compromise* alternative from the reasonable alternatives, where 'best compromise' means the alternative that best reconciles the different interests, or simply the one upon which they manage to agree. In many cases, this phase is simply a comparison (if there is only one DM) or a negotiation process (if there is more than one) of the reasonable alternatives, which is often carried out with less formalized methods than those used in Phase 7, taking account of the customs and local culture. Sometimes, however, the DM(s) feels the need to explore new alternatives or introduce new criteria. In that case the phase is transformed into a new cycle of Phases 1–8.

The last three phases are the core of the decision-making process and, together, they are framed in greater detail in Chapter 16, before each phase is addressed separately in the chapters that follow.

1.3.2 Remarks

Often the importance of phases that have an engineering or modelling character (in particular *Identifying the Model* (Phase 3) or *Designing Alternatives* (Phase 4)) is emphasized, at the expense of more socio-political phases, like *Defining Criteria and Indicators*, *Evaluation* and *Comparison*. This is a mistake, since a correct decision can be taken only when the expectations, desires, images, knowledge, problems and fears of the Stakeholders are as well described and understood as the physical, technical and economic aspects of the system. Therefore, not only are Phases 3 and 4 of equal importance to the others, and must be considered as such, but the participation of Stakeholders should be full and continuous in all the phases, because only in this way will negotiations in Phase 7 be successful. We will never tire of repeating that if the Stakeholders do not believe in the index values that are shown them in that phase, they will never be willing to negotiate. Actually, they will probably not decline to participate in negotiations, but these latter will develop laboriously, with Stakeholders that listen passively or react aggressively and the result, even if formally it can be achieved, will not really change anything in the existing conflict.

Not all the phases are always necessary. If, for example, in Phase 2 only one criterion is identified, the decision-making process concludes with Phase 4 (or at best with Phase 5). If, instead, there is only one DM and she does not intend to activate a participatory decision-making procedure, the process concludes with Phase 6. If there is no DM above the Parties that participated in negotiations, it makes no sense to go through Phase 9.

It is important to underline that the real development of the decision-making process is not serial as Figure 1.4 might lead one to think. Besides the recursion between Phases 4–5–6–7–8, which is explicitly highlighted in the figure, many others can appear. For example, the criteria cannot actually be correctly identified if one does not known the actions being considered, since these latter produce the effects that the Stakeholders endure. On the other hand, it is not possible to identify the actions without knowing the interests at stake, and therefore the criteria. The presence of recursions is essentially due to the fact that in carrying out the decision-making process new information is produced, because it is a process of *social learning* (Renn, 1995). In view of the new information that is acquired, it is then necessary to re-examine the conclusions of the phases that were considered to be already finished and, when necessary, to modify them. In one sense the aim of the decision-making process is to increase the actors' understanding about the Project, so that they can formulate more and more precise requests and justified opinions.

The PIP procedure has to be supported: except for the phase of *Recognition*, all the phases must be handled by an appropriate set (*toolbox*) of ICT (Information and Communication Technologies) tools, which its users must perceive as part of a unique and coherent system, i.e. a Multi-Objective Decision Support System (MODSS). In the literature this term is sometimes used only in relation to Phases 6 and 7, but we consider this to be inappropriately restricted.

The PIP procedure has to be managed: in all the phases the Stakeholders must be assisted by the Analyst, for the more technical aspects, and helped by a Facilitator as far as organizational and relational aspects are concerned (see Appendix A10).

Finally, it is important to underline that there is a difference between a phase and the method used to implement it in a given context. The phase defines a methodology, i.e. a set of methods and the rules to choose between them. Thus there is not a one-to-one, but a one-to-many relationship between phases and methods. The aim of the chapters in Parts B, C and D of this book is to illustrate these very relationships.

1.3.2.1 The FOTE paradigm

Negotiations and relations among the Parties are easy or difficult in relation to the degree to which they share and exchange information about the problem, the system and their own personal interests; that is the degree to which they adopt a paradigm of *Full Open Truthful Exchange* (FOTE) (Raiffa et al., 2002). This is why the PIP procedure does not begin with negotiating the alternatives, but instead with an information exchange (Phase 0). It goes on with a participatory definition of the actions (Phase 1), the enunciation of the interests (Phase 2), the identification of a shared model of the system (Phase 3). Not always do the Parties involved agree to adopt the FOTE paradigm; however, the Analyst must always suggest its adoption because, otherwise, the Parties might not make the most of their potential synergies. With FOTE paradigm certain basic concepts such as efficiency and equity, along with the reservation values that each side has, gain clarity and crispness of definition, but even when the paradigm is not completely satisfied the analysis made on its basis is still useful, particularly when the Parties agree to tell the truth but not necessarily the whole truth, for example when they are reluctant to disclose their reservation values (BATNA, see Chapter 21). It takes two to tango: it may happen that idealistically one Party is willing to negotiate in a FOTE style, but they are not able to trust the other Party. In that case the FOTE approach is impracticable, but even then FOTE remains a benchmark by which to judge the line of action.

1.3.2.2 Data

Do not underestimate the essential role that the data, and the methodologies for their acquisition play in the decision-making process. The data are used, in a qualitative way, in the phases of *Recognition* and *Defining Actions*, and in a quantitative form in Phases 2, 3, 4, 5 and 8. Their quantity, availability and accuracy are essential to the success of the decision-making process, but even more important is that all the Parties believe that the data are valid and meaningful. The credibility of the model, which is the basis for the credibility of the evaluation of the alternatives, is founded upon this belief, without which the negotiation process is a fruitless exercise. In simple terms: the entire decision-making process depends on the social acceptability of the data.

1.3.2.3 Uncertainty

Ignorance is being unaware that our knowledge is imperfect. An imperfect knowledge implies uncertainty and uncertainty generates apprehension. For this reason, DMs often have the tendency to remove the problem of uncertainty: they want scenarios to be deterministic and models to provide exact estimates, so that their evaluations will be perfect. However, hiding uncertainty is none other than a form of ignorance. Thus, in many phases of the PIP procedure the problem of treating *uncertainty* arises. Uncertainty is produced by corrupt, insufficient or scarce information, and by the errors that are committed unknowingly. We will see in the following that all these causes can be represented as the effects of *disturbances*, which can assume different forms: disturbances are *stochastic* when we know or we can estimate their probability distributions; they are *uncertain* when we know only the set of values that we guess they might assume. The form of a disturbance depends upon the source that generates it. For example data collection generates the most common uncertainty: *measurement errors*, which are always described as stochastic and afflict all the phases in which the data are used. In Phase 1 uncertainty appears also in the description of the actions, since the way in which they will actually be implemented is not always certain (implementation uncertainty); this uncertainty is not only due to implementation aspects, but also to institutional inertia. In Phases 3 and 6 one must account for the disturbances that can make the design and evaluation scenarios uncertain: it is when confronted with this type of uncertainty about the future that DMs and Stakeholders reveal their aversion to risk, which we discussed in the description of Phase 2. In Phase 3 it is necessary to take into account the so-called *process errors*, i.e. the eventuality that the model does not perfectly describe reality.

The effects produced by all these disturbances combine to generate the uncertainty that afflicts the indicator values that make up the Matrix of effects. One must keep this fact in mind in Phases 6–9. The methods with which to do this will be described further on. In particular, Chapter 23 is devoted to a recapitulation of the different types of uncertainty that affect the decision-making procedure and of the techniques that have been proposed to handle such uncertainty.

1.3.3 The Project scheme

The very concept of a Project requires the definition of a mental scheme of the system and its evolution in time, subject to the joint action of the events that would naturally occur, and the implementation of an alternative. The scheme that is commonly adopted is shown in Figure 1.6, where the system is described on the vertical axis, following the DPSIR framework that was introduced at the beginning of the chapter, and time is represented on the horizontal axis.

The decision-making process is considered to be instantaneous, because its duration is negligible with respect to the duration of the following phases, which generally covers several decades. It is placed in the origin of the time axis. Decision-making is followed by the *implementation* period (see also Figure 1.2), during which the chosen alternative is implemented. This period can last from a few months to many years, but the most frequent case is the second, and it ends with the beginning of the *management* period, which is assumed to

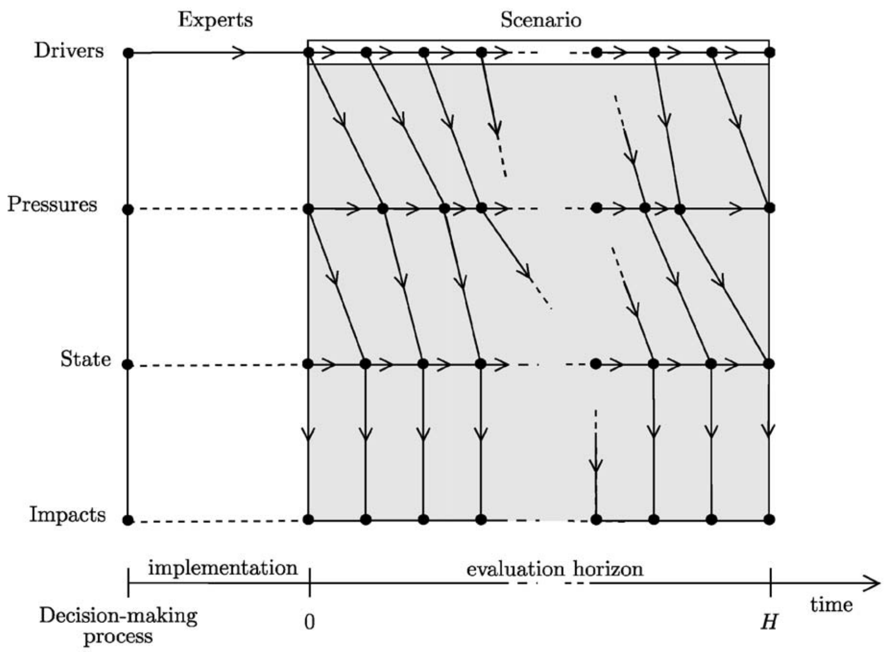

Figure 1.6: The Project scheme for a dynamical system.

extend over a time horizon called *evaluation horizon*. Decision-making requires the estimate of the effects that each alternative would induce over the whole evaluation horizon. During this period the system is subject to the action of the Drivers (in the 'enchanting lake' example, with which we opened the chapter, these are agricultural, industrial and civil practices that produce nitrogenous substances that reach the lake, as well as the rain that generates the lake inflow). As the figure shows, not only does the evaluation horizon extend over time in a significant way, but its starting point is separated from the time instant at which the decision-making process is developed by the duration of the implementation, which, as we have said, is often many years. It follows that it is hardly ever possible to adopt the Drivers' pattern that was recorded in the past, and therefore it is necessary to ask the Experts to predict its future evolution, i.e. to provide a *scenario*. Developing this scenario is not easy, and this is why often the Experts provide several *alternative scenarios*. To generate each of these the Experts can use the behaviour of other variables, termed *external or exogenous*, and they can make use of models (in the 'enchanting lake' example they could use a climate change model to provide the rainfall scenario, in which case the exogenous variable would be the behaviour of the greenhouse gas emissions). By doing so, however, the system being studied has clearly been enlarged (in the example, the climate system that determines the rainfall pattern has been added to the lake) and the external variables are none other than the Drivers of the enlarged system. It would thus seem opportune to redefine the system but, when actions that influence the added system (in the example, the Kyoto protocol which acts on the climate system) are not considered, it is advisable to keep the original description of the system (i.e. consider the lake alone).

The system being studied is almost always a dynamical system and, as such, its condition (state) at the beginning of the evaluation horizon is the result of what will happen to the system during the implementation period. Nevertheless, this is taken into account only in the development of the executive Project, when also the so-called *construction phase* (i.e. the implementation period) is considered. Instead, when the alternatives are screened to find the best compromise alternative, that phase is ignored, since it would be too onerous to take it into account. The consequence of this omission is that the Experts must also provide an estimate of the state of the system at the beginning of the evaluation horizon (the so-called *initial state*).

For the whole evaluation horizon it is necessary to explain how the variation of the Pressures is influenced by the variation of the Drivers, how the former influence the State which, in turn, produces the Impacts. It is the task of the *system model* to describe these transformations. The *actions* of which the alternative is composed play a very important role in such transformations, and so it is essential that the model permit an accurate description of them. When the system is proper and dynamical[39] a variation in the value of the pressure does not result instantly in a variation of the state and, in turn, the state varies progressively in time not only owing to the action of the pressure, but also as a function of its current value (this is the actual meaning of the term 'dynamical'). The same thing occurs very often between Drivers and Pressures, while almost always the Impacts are in a non-dynamical relation with the state. In other words the scheme of the cause–effect relationships among these variables is the one described by the arrows that appear in the grey rectangle in Figure 1.6, which individuates the space–time domain described by the model of the system. Sometimes, however, to simplify the description, one assumes that the system is not dynamical, so that the cause–effect relations become those described in Figure 1.7.

Very often the system is not just dynamical, but also extended over space (i.e., in jargon, it is a *distributed-parameters* system), as is, for example, a river (see also Appendix A1). In that case, the state of the system is at every moment characterized by the spatial patterns of the quantities that characterize it (flow, level and concentrations, in the example of the river) and, since these patterns evolve over time, the evolution of the state is represented by a surface as in Figure 1.8 (see Rinaldi et al., 1979).

The description of these systems is particularly onerous (it requires partial differential equations rather than total ones) and this is why often one looks for a way to simplify their description. The most common solution is to consider the system only in *steady-state conditions*, i.e., when its state has reached an equilibrium. This occurs when the spatial trend of the quantities that describe it does not change over time and so the evolution of the state is described by a surface whose temporal sections are all equal (see Figure 1.9a). Clearly, this condition occurs only when the Drivers do not vary in time, so that each of them is defined by a single value. In steady-state conditions the system is often described by the viewpoint of an observer who moves through space: for example, in the case of a river, the concentration pattern is described from the point of view of an observer who travels downstream on a boat that is carried by the current (see Figure 1.9b). By doing this the description of the system is brought back to the sphere of models that are defined by full differential (or difference) equations, i.e. of *lumped-parameters* models, in which the independent variable is space, or better still the flow time, i.e. the time that has passed from the moment when the observer left the first section. When one decides to consider the system in steady-state conditions, the

[39] The terms are defined in Appendix A3.

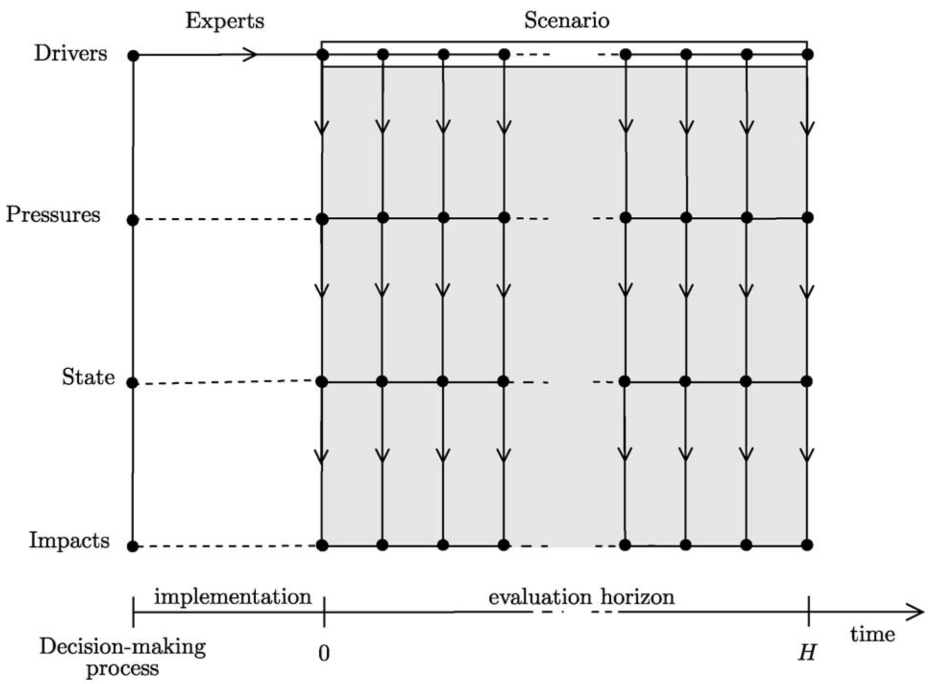

Figure 1.7: The Project scheme for a non-dynamical system.

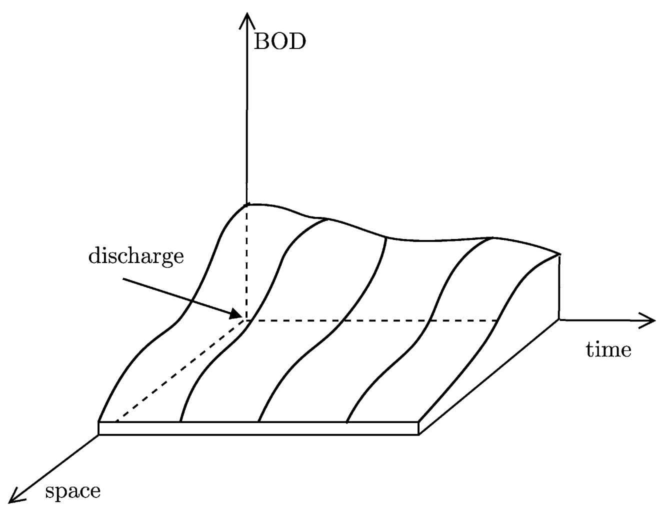

Figure 1.8: The evolution over time, downstream of an effluent point, of a component of the state (concentrations of BOD) of a river, whose initial flow varies because of the regulation (Driver) of a reservoir.

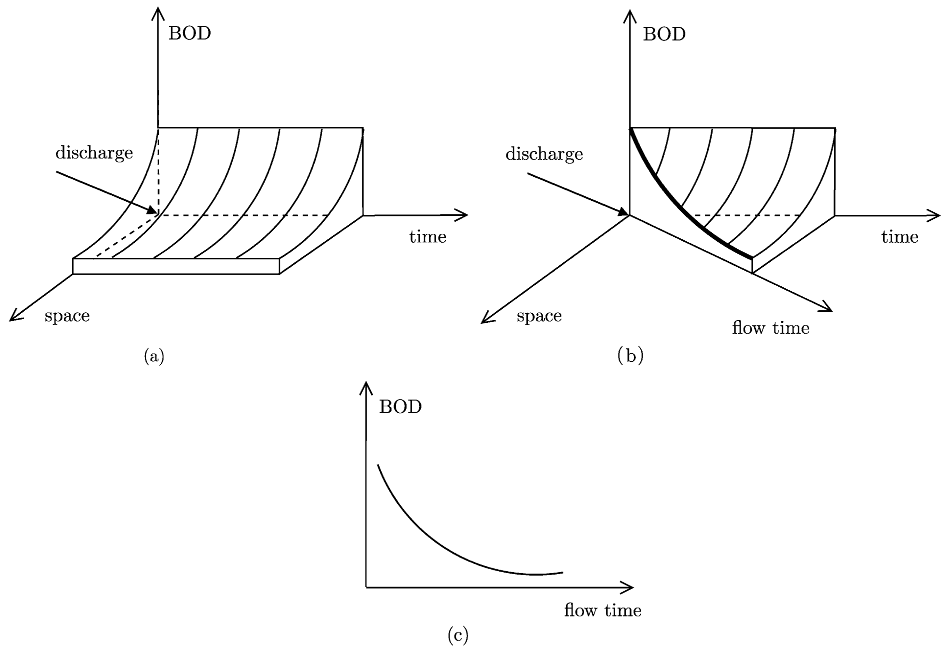

Figure 1.9: The temporal evolution of a state component (concentration of BOD) in the river of Figure 1.8, when the reservoir release is constant over time and the system is in steady-state conditions (a); the same from the viewpoint of an observer who travels down the river in a boat and defines the position of the boat by the time passed from the beginning of the journey (flow time) (b, the bold line); the same as it is represented by the observer (c).

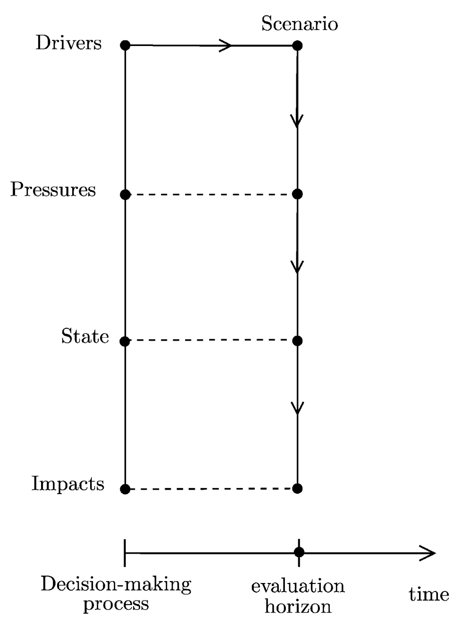

Figure 1.10: The Project scheme when only steady-state conditions are considered.

evaluation horizon contracts to a point and the diagram in Figure 1.6 is transformed into the one in Figure 1.10. An example of this case is described in Appendix A1.

1.3.4 Evaluating Alternative Zero

It is not always evident a priori whether the Alternative Zero ('no actions'), would be sufficient in and of itself to attain the Project Goal. In this case, before beginning the decision-making procedure, the Analyst is often tempted to ascertain if this is true by using a shortcut: he fixes the evaluation scenario and on that basis simulates the effects of the Alternative Zero. By doing so he can see whether it is necessary or not to intervene. The following example may help the reader to better conceive this problem.

The WFD requires that by 2015 all European rivers will have achieved "good status" and that by 2009 each member state will have defined a "plan of measures" (i.e. the alternative, according to the terminology of this book) that are necessary for attaining that Goal. Before designing the plan, the Seine-Normandy River Basin Authority in France clearly wants to ascertain whether the actions that have already been programmed along the Seine from now until 2015 would be sufficient by themselves to bring the river to 'good status'. This is why they decide to estimate the presumed conditions of the sources of pollution in 2015 (i.e. the baseline scenario), with which they simulate the condition of the river in that year. Thereby, they obtain an estimate of the future 'status' of the water system (see Appendix A1).

In our opinion this way of proceeding may create problems in the event that the Alternative Zero proves to be unable to meet the goal. The reader should remember, in fact, that the scenario is none other than the behaviour of the Drivers over the entire evaluation horizon. These Drivers are those input variables of the system model upon which the DM cannot act, i.e. the variables that are not influenced by any of the actions considered. The definition of the scenario, therefore, cannot be done without defining, at least implicitly, the actions that are being considered (Phase 1) and the criteria (Phase 2) by which their effects are evaluated. From these last two definitions follow the definitions of the input and output variables of the model with which the system is represented (Phase 3). From them and from the definition of the actions, the Drivers with which one wants to predict the system behaviour emerge, i.e. the scenario emerges (Phase 5). If these phases are not carried out explicitly, the Analyst runs the risk of discovering a posteriori that the scenario was identified incorrectly. This may emerge once the Alternative Zero has proved to be insufficient for meeting the Project Goal, and all the choices that were previously implied are made explicit, in implementing the PIP procedure. If this should happen, the Analyst would be seriously embarrassed.

It is true, however, that, when it is not evident a priori, ascertaining whether the Alternative Zero alone would be sufficient to attain the Project Goal is clearly the first thing to do. But the correct way to do this is to carry out a first iteration of the PIP procedure, during which in Phase 1 only the actions that have already been deliberated are considered, thus being an integral part of the Alternative Zero; Phases 2 and 3 are carried out as stated in the PIP procedure; Phase 4 is omitted; in Phase 5 the scenario is defined and the effects that the Alternative Zero produces are estimated. These effects are evaluated in Phase 6; Phase 7 is limited to verifying whether the Project Goal has been achieved and, if the response is negative, one returns to Phase 1 to identify actions that are suitable to attain it. This example is developed in greater detail in Appendix A1.

1.4 Management

Once the best compromise alternative has been selected (Phase 9 of the PIP procedure), it has to be implemented (see Figure 1.2): this is achieved by implementing the structural and normative actions it includes, and applying the regulation policy, if this has been designed, at the scheduled time instants. Since this policy may leave some degree of freedom to the Regulator (see Section 10.1.1 on *set-valued policies*), a decision-making problem must be formulated at the *management level* as well, though the degree of freedom that the policy allows is much less than the degree that the DM had when the problem was formulated at the *planning level*, i.e. at the level that we have been considering until now. The best compromise alternative is therefore at the same time the conclusion of the decision-making process at the planning level and the starting point for the decision-making process, which is renewed periodically, often daily, at the management level, on the basis of the new information which is obtained as the time goes on.

1.5 Monitoring

Once the best compromise alternative has been implemented and management has begun, the effects that are produced should be monitored (see Figure 1.2) continuously over time, in order to make sure that the real effects are actually those that were foreseen. Should they not be, it is necessary to open a new cycle of intervention. We will not deal with monitoring in this book, but the interested reader may consult UNECE (1990) and Wiersma (2004).