Chapter 4

How to Make IAs More Rigorous

4.1 HIGHLIGHTS

This chapter tests the premise that IA processes, documents, and methods should be more scientifically rigorous. Chapter 1 identifies the lack of scientific rigor as a recurrent shortcoming of IA practice. This chapter seeks to address that shortcoming.

- The analysis begins with two applied anecdotes. The stories describe applied experiences associated with efforts to make IA practice more rigorous.
- The analysis in Section 4.3 then defines the problem, which is the inadequate and ineffective use of scientific principles, knowledge, and methods in the IA process. We provide practical advice for making IA documents and processes, at both the SEA and project EIA levels and for various IA types, more rigorous, while allowing for the limits of science in IA practice.
- In Section 4.4 we identify relevant principles and assumptions commonly ascribed to analytical science. Debates concerning analytical science are explored both in general and for applied fields such as IA. These analyses provide the basis for defining a rigorous IA process.
- In Section 4.5 we detail how a rigorous EIA process could be implemented at the regulatory and applied levels. In Section 4.5.1 we infuse a "scientific" perspective into IA regulatory requirements and guidelines, in Section 4.5.2 we integrate a "scientific" perspective into applied processes, and in Section 4.5.3 we address IA theory building at the SEA and project EIA levels, and for various IA types (SA, EcIA, SIA, and HIA).
- In Section 4.6 we address the contemporary challenge of good practice follow-up approaches. We address both good practice ends and means and present an array of regulatory and applied level examples of follow-up good practices.
- In Section 4.7 we highlight the major insights and lessons derived from the analysis.

4.2 INSIGHTS FROM PRACTICE

4.2.1 Poor Practice Rides Roughshod Over Sound Theory

Located in the Peace Region of British Columbia (BC), Canada, the Hermann Coal Mine Project was proposed at a time of heightened concern by resident indigenous groups over the compromised health of the local ecosystems. The region was (and likely still is) the quintessence of cumulative impacts. Examples of the intensity and diversity of development projects approved as of 2012 include approximately 18 000 oil and gas well sites, 10 000 industrial facilities, 6000 forestry cut blocks, 5 coal mines, 6 wind farms, 2 large-scale hydroelectric dams, 60 000 km of roads, and 100 000 km of pipelines. None of the existing projects, however, included a SIA that adequately examined project-specific (let alone cumulative) impacts upon the cultural values held by the indigenous groups.

In October 2006, the BC Environmental Assessment Office (EAO) released the draft terms of reference (TOR) for the EIA of the Hermann Mine to the public for their review and comment. Since a draft TOR is modified in some cases (before finalization), in order for the EIA to respond properly to the concerns of the public, an indigenous group took the opportunity to provide constructive, science-based comments with the intention of making the SIA more culturally inclusive.

Considerable emphasis was placed upon the theoretical orientation. The proponent's use of the "modernization paradigm" as the basis for the SIA was viewed by the indigenous group to be highly problematic, since it assumes (albeit erroneously) that industrial development is inherently beneficial to them and that their culture will inevitably be assimilated into mainstream society such that their land-based economy will be replaced with one that is industrial based. They also noted that the proponent's theory led to the selection of valued social components (VSCs), specifically, housing, transportation, services, labor supply, and community health conditions, which would not accurately assess impacts to their cultural values. Overall, the framework did not adequately take into account the essence of their cultural traditions, customs, and land-use practices, or of the cumulative impacts to such values.

Impact Assessment: Practical Solutions to Recurrent Problems and Contemporary Challenges, Second Edition. David P. Lawrence.

An appropriate remedy, in their view, was the application of the "subsistence/adaptation paradigm" as a way to properly ground the SIA. Because that theory places a significant emphasis on the ability of indigenous groups to preserve cultural lifestyles and the ability to mix the traditional economy with the mainstream economy in situations where integration maintains or enhances cultural integrity, the selection of VSCs reflecting this theory would echo their cultural values. They recommended the SIA use the following VSCs: livelihoods and economic vitality, population structure and health, social stability and community well-being, education and training, and cultural well-being.

Irrespective of the fact that the approach put forward by the indigenous group was in tune with socioscientific standard of SIA research, the proponent stated that it was not going to revise the scope of work, and thus refused to modify the draft TOR. Its reason was simple: The company planned to submit the EIA report by mid-November 2006 (mere weeks after the public comment period ended), and thus did not have the time to change its design and methodology. This shed light on the proponent's predisposition; that is, it likely had no intention of seriously considering or integrating input into the TOR if such a change increased the risk to its project. Not surprisingly, the EAO and the indigenous group disagreed with the proponent's response, which was, at a minimum, contrary to the principle of soliciting input in good faith. The feedback from the indigenous group was considered by the EAO to be scientifically credible, and as such, the proponent was forced to include the Indigenous approach and chosen VSCs in the final TOR.

Without collecting the relevant primary or secondary data to address the data gaps, the proponent submitted its EIA report two months later. The EAO (unexpectedly) accepted the report even though it failed to fulfill the requirements of the TOR; indeed, the document admitted that the assessment was "incomplete" and the proponent did not have the necessary data to assess impacts to culture. None of the indigenous groups took the decision lightly. They boycotted the process and insisted that the timelines be suspended until the impacts to their cultures were adequately assessed. The EAO initially declined to suspend the process, but did so after the proponent (albeit reluctantly) agreed.

Neither the data gaps nor the assessment of the potential impacts to cultural values were, by the end of the suspension period, reconciled. The Hermann Mine was subsequently approved by BC although it lacked a scientifically rigorous and culturally appropriate EIA. What this case revealed was that SIA theory may have come a long way since its inauguration in Canada approximately 40 years ago, but its current practice remains fixed in the domain of public policy (based on heartland–hinterland ideologies) rather than sound scientific analysis.

BRUCE R. MUIR

CTQ Consultants Ltd., Kamloops, British Columbia, Canada

4.2.2 Better Science = Better Decisions: the Case of Igamba Falls

The Kigoma region of western Tanzania is desperately short of power; less than 3% of households are supplied with electricity. Electricity is supplied by the Tanzania Electricity Company using old diesel-powered generators that are no longer capable of operating at full capacity. As the diesel fuel has to be transported by rail from the port of Dar es Salaam, 1200 km (750 miles) away, both the supply of fuel and the electricity generated are erratic and expensive. The region is not linked with the national transmission grid. This inadequate supply of electricity greatly hinders industrial development and regional economic growth. The Government of Tanzania recognized in the mid 20th Century that improved electrification of the Kigoma region will have many beneficial impacts, and has been actively looking for ways to provide it with an adequate, reliable, and affordable supply of electrical power.

Since the early 1980's the Tanzanian government has been working closely with the Joint UNDP/World Bank Energy Sector Management Assistance Program. An early initiative was a 1982 feasibility study of the potential for mini hydropower development in the region. This study explored the possibilities of hydropower development on the Malagarasi River at the 20 m high Igamba falls about 60 km southeast of Kigoma. Although hydropower generation at the falls was technically feasible, this early study concluded that the Igamba Falls project was uneconomic, even with funding from the World Bank, and was thus not pursued.

During 2004–2005, a further study by a different international consultancy undertook a prefeasibility study of a modified plan for hydropower generation at the Igamba Falls. This study collected extensive topographic, environmental, social, geological, and hydrological data. Sections of the report dealt with aquatic environment, water quality, sediment load, terrestrial ecology, land use and vegetation cover types, habitat assessment, geology and soils, landscape and land use, settlement patterns and land tenure, demography, sources of income, currently protected areas, and a proposed protection area. Particular attention was given to several features of the project site. The unusual geology—highly fractured calcareous sandstone that allows a lot of water to flow underground through fissures and solution channels—caused concern and required an explorative drilling program. The barrier that the falls posed to aquatic migrations, and thus to potential species separation, was recognized and led to a comparison of fish being caught above and below the falls by indigenous fishermen. Although the site impinges marginally on the Masito Conservation Area—known for its chimpanzee population—the fact that the project requires a bridge across the river, was recognized as a problem as this would facilitate human access to the conservation area. The study proposed measures to overcome these negative impacts. Nevertheless, the economic and financial analyses indicated that the project would not be viable unless it could be financed from a "soft loan" repayable at low interest over 30 or more years.

During 2005 a team of international scientists, led by Dr Ellinor Michel of the British Natural History Museum, undertook a three-week survey of the 450,000 ha Malagarasi-Moyovosi wetlands. This biodiversity and limnological study was completely unrelated to the hydropower project and was undertaken because the Malagarasi drainage in western Tanzania is among the world's most important, yet least studied, wetland regions. Detailed biological sampling took place at 40 sites, one of which was external to the wetlands and in the gorge through which the Malagarasi River discharges into Lake Tanganyika: serendipitously, the site of the proposed Igamba Falls hydroproject was surveyed because a track to the river had been opened to allow access for hydroproject vehicles.

Sampling of the Igamba Falls led directly to the statement in the report: "Our aquatic surveys of the remote Igamba Falls . . . revealed a number of new fish and mollusk species, making this site not only of special interest, but also of special concern as it is under discussion for hydropower installation. . .. Our aquatic sampling there was of very limited duration and we strongly advocate detailed biodiversity work be continued in the region."

In 2008 the Tanzanian Government (GoT) entered into a compact with the Millennium Challenge Corporation (MCC), created in 2004 by the Congress of the United States of America. The compact allows for grants to projects in the energy sector that will reduce poverty through economic growth, increased productivity, and raised incomes. This compact opened the way for immediate action on the previously planned and studied 8 MW run-of-river hydropower plant at the Igamba Falls.

The earlier environmental and social impact assessment (ESIA) was quickly updated by an international consultant, but was found inadequate by the National Environment Management Council in Tanzania and by the MCC. A further ESIA was consequently commissioned from a different international consultant to meet MCC environmental and social guidelines and GoT requirements. This contract required detailed feasibility studies, a baseline aquatic survey at Igamba Falls, as well as a comprehensive cumulative impact assessment for the project. But, unaware of the results of the Michel et al. survey, the terms of reference failed to specify the extensive surveys and analyses necessary for a scientifically sound examination of project impacts on endemic species, in particular the new fish and snail species that had been found.

In early 2009, the MCC became aware of the significant biodiversity questions raised by Dr. Michel and her colleagues and recognized that specialized expertise would be necessary to address the issues raised and contribute to the project's ongoing environmental assessment. A further study by internationally acclaimed scientists was therefore commissioned to allow assessment of the biological significance of the three new species that had been previously discovered at the Igamba Falls to determine whether these species exist anywhere else and whether mitigation measures could ensure that they would survive the construction and operation of a hydropower facility.

This supplementary study confirmed that the Igamba Falls are unique. Their geology and geomorphology are most unusual, the calcareously bound sandstone is fractured, and scour holes and solution channels are ubiquitous. Subsurface water flows through horizontal strata and vertical joints creating a unique habitat. Water chemistry in the Igamba Falls area differs from that upstream and downstream, and biological productivity is substantially different from any other site on the Malagarasi River. Consequently, the flora and fauna of the falls are unique. The study also found that that the physical, biological, and chemical character of Igamba Falls would be fundamentally changed by the hydropower project, and that mitigation measures needed much more study.

An independent advisory panel (IAP) of international and Tanzanian experts was appointed to review all relevant studies and to suggest a way forward. The IAP found that the Igamba Falls did require special consideration due to their unique ecological, geological, and hydrological characteristics. It identified many significant impacts that would occur should the project go ahead as planned. Consequently, steps and further studies to protect the unique habitats and their endemic flora and fauna were recommended.

Despite a strong desire to fund the hydropower project to promote regional development and alleviate poverty, the MCC was faced with the requirement in its founding legislation that it may not finance projects that are "likely to cause a significant environmental, health, or safety hazard." Consequently, the MCC reached the conclusion that it could not fund the Igamba Falls hydropower project. Some viewed this decision as "snails being more important than power and development," particularly as none of the species have economic or cultural value. Other commentators concluded that development and poverty reduction were being sacrificed on the altar of biodiversity.

The Igamba Falls project contains several lessons for impact assessment professionals: First, the need for utmost caution and unusually thorough scientific investigations whenever projects are being planned in locations that have highly unusual physical features likely to give rise to rare habitats and endemic species. Second, no matter how well the environmental and social assessments are planned, be prepared for serendipitous discoveries and do not jump to premature conclusions. Scientific studies unrelated to formal ESIAs can, and should, inform project assessments. Third, studies of noncharismatic and noncommercial species are as important as studies of popular or commercially important species. Biodiversity assessments are an important aspect of environmental investigations. Finally, rapid assessments by highly qualified, experienced investigators can produce results that were overlooked by less experienced persons, even when working more slowly.

Postscript: The MCC has subsequently worked with the GoT to provide other options to meet Kigoma's electricity needs. These include repairs to generators and increased use of solar energy. The MCC also financed, at the request of the GoT, feasibility and environmental studies of another potential downstream location for a different Malagarasi hydroproject. That option would permit other donors, if the environmental impacts of the downstream location can be mitigated, to invest in the project and link the power generated into the Tanzanian grid.

RICHARD FUGGLE

Environmental Evaluation Unit, University of Cape Town, Cape Town, South Africa

4.3 DEFINING THE PROBLEM AND DECIDING ON A DIRECTION

The preceding stories demonstrate that there is potential role for the sciences in the IA process. The first story illustrates how the lack of sound, contextually appropriate, social science, especially if not effectively married with community and indigenous knowledge, can undermine IA credibility and effectiveness. The second story demonstrates the importance of a cautious approach to applied science in uncertain and sensitive environments, the need to extend the consideration of biodiversity to encompass noncharismatic and noncommercial species, the potentially significant decision-making role of biodiversity, and the value of highly qualified and experienced scientific investigators.

Critics of the prevailing and, in their judgment, too limited role of science in IA practice argue that IA processes, documents, and methods are too often ill defined, biased, subjective, and excessively descriptive (Whitney, 1986). They generally point to the limited foundation of sound scientific theory and knowledge (Dimento and Ingram, 2005; Greer-Wooten, 1997). They note that objectives are usually poorly stated. Study designs and standards of inquiry, they suggest, tend to be weak to nonexistent (Whitney, 1986). The methods applied, they point out, are far more simplistic than those formulated and applied by researchers (Lee, 2006). Commonly, they argue, spatial and temporal boundaries are either not defined or are defined too narrowly (Galbraith et al., 2007; Greer-Wooten, 1997). They indicate that the methods for characterizing environmental conditions, predicting changes with and without the proposal, and for managing effects are frequently vague, overly descriptive, poorly substantiated, and inconsistent with the scientific standards and protocols (Beanlands and Duinker, 1983; Greer-Wooten, 1997).

The critics tend to express particular concern with the limited attention devoted to the variability of natural phenomena, to social impacts, to environmental and impact interactions that transcend disciplinary boundaries, to cumulative effects, to comparable proposals and environments and to the postapproval monitoring and auditing of environmental conditions, the accuracy of impact prediction and the effectiveness of management measures (Burdge, 2004; Devlin and Yap, 2008; Hansen and Wolffe, 2011; Morgan, 1998; Noble, 2009b; Whitney, 1986). They further contend that qualified scientists are insufficiently involved in conducting and peer reviewing IA documents, methods, and procedures (Brown, 1986). These deficiencies result in, the critics conclude, unreliable predictions, avoidable uncertainties, an unsound decision-making basis, limited decision-making influence, the diminished credibility of science and scientists, a negligible contribution to the accumulation of knowledge, and a degraded environment (Dimento and Ingram, 2005; Morgan, 1998; Morrison-Saunders and Sadler, 2010; Whitney, 1986).

These views are not uniformly shared. Many argue that there are numerous dangers associated with a more scientific IA process. Some even suggest that a scientific IA process is inherently inappropriate. Between these two poles is a considerable middle ground occupied by those who would selectively apply, adapt, temper, and modify analytical scientific methods and principles. Further complicating the issue is a plethora of alternative conceptions of the nature and role of science as it is and as it could be applied for planning and decision-making purposes.

The journey from a desire for a more rigorous IA process to its application, therefore, involves intermediate steps. First, an overview of the principles and assumptions commonly ascribed to analytical science needs to be provided as a point of departure. Then debates regarding if and how analytical science might be modified in general and for applied fields such as IA need to be explored. The guidance for implementing a rigorous IA process addresses management at the regulatory and applied levels. Theory building variations between the SEA and project EIA level, and among IA types, are explored. Particular consideration is given to good follow-up practices. Ideal IA process criteria are used to identify the positive and negative tendencies of a scientific IA process.

4.4 SELECTING THE MOST APPROPRIATE ROUTE

The debates surrounding the applied role of science tend to treat classical analytical science as the "touchstone." Analytical science is viewed by some as a role model for applied fields such as IA. Others focus on its characteristics in making a case either against the use of science or in favor of substantial adaptations. Table 4.1 lists examples of terms that commonly crop up in the debate. Table 4.2 identifies characteristics often ascribed to analytical science. These characteristics sometimes operate in dramatic tension. Almost all analytical science characteristics are intensely debated. Any exploration of science in IA must inevitably

Table 4.1 A Few Key Terms in Analytical Science

Applied theory	• Findings applied to the solution of problems • Focus on facilitating decision making
Deduction	• Logical rules determine general premises, hypotheses, or theories • Conclusions about particulars follow from general premises • Testing approach often referred to as hypothetico-deductive method
Empiricism	• Research orientation that emphasizes facts, observations, and experiences over theory and conceptual reflection
Grounded theory	• Grounded in data obtained by research (contrasts with formal abstract theory)
Induction	• Process leads from particular facts and observations to general conclusions
Knowledge	• True belief acquired by a reliable method
Normative theory	• Hypotheses or other statements about what is right or wrong, desirable or undesirable, just or unjust in society
Positivism	• Rejects metaphysical speculation in favor of observation and experimentation as the preferred source of knowledge about the world • Aims to construct general laws or theories which express relationships between phenomena
Principles	• General rules for constructing models
Reductionism	• Belief that all phenomena can be reduced to a few laws and principles
Rigor	• Strict precision; exactness
Science	• A systematic series of empirical activities (methods) for constructing, representing, and analyzing knowledge about phenomena being studied • A set of normative commitments shared by a community of scholars • An occupation (scientists seeking to establish a body of knowledge) • Knowledge (tested facts and theories) • Applied to human needs and purposes (when applied rather than basic or pure science)
Scientism	• The claim that the positivist method is the only true method of obtaining knowledge
Theory	• A collection of hypotheses and predictions amenable to experimental testing • Organizes our concepts of and understating of the empirical world in a systematic way • A guide for defining what type of observations need to be made to understand phenomenon • A guide for interpreting observations

Sources: Bird (1998), Cashmore (2004), Giere (1999), Gower (1997), Patterson and Williams (1998), Rothman and Sudarshan (1998), Wilson (1998).

touch on some of these "science wars" debates (Giere, 1999). The following subsections highlight the implications of the "science wars" for IA theory and practice.

4.4.1 Absolute Truth Versus Relativism

The absolute truth versus relativism debate suggests that IA practitioners need not be constrained to a choice between the quest for absolute truth and the "anything goes" perspective of relativism. IA practitioners can draw upon the insights and methods of the natural and social sciences to enhance understanding, facilitate explanations, and contribute to improved decision making. As illustrated in Figure 4.1, IA practice can make a small contribution to middle-range theory building and successively greater contributions to micro theory building and pre-theory. These contributions will undoubtedly vary greatly in their quality, accuracy, scope, simplicity, and fruitfulness (Gower, 1997). They may not fully satisfy the "standards" of analytical science. A "tidy" hierarchy of mutually consistent and supportive theories is unlikely to emerge. A plurality of overlapping and often competing theories is the more likely result. But these efforts can, when due allowance is made for contextual variations, improve our understanding of and our role within the environment.

Much IA practice is either atheoretical or at the pre-theory level. Nevertheless, carefully formulated, applied, shared, and refined IA models, designs, concepts, frameworks, precedents, lessons, and tightly circumscribed generalizations still can lift IA practice beyond an exclusive focus on individual proposals and settings. A core body of good-practice IA knowledge is emerging. This process has accelerated in recent years with the proliferation of IA quality and effectiveness analyses, and with substantial theory building initiatives for individual IA types. The construction of an IA knowledge base cannot and should not be limited to the application and adaptation of a narrowly defined range of scientific perspectives and procedures. The claims and contributions of other scientific and nonscientific perspectives and of other modes of reasoning also must be recognized and accommodated (Healey, 1997). It will often be helpful to view IA related issues from multiple perspectives (sometimes this means alternative worldviews) and to apply multiple scientific and nonscientific paradigms and methods (Patterson and Williams, 1998). It is especially important that nonscientists be given a voice, expressed,

Table 4.2 Characteristics Commonly Ascribed to Analytical Science

Objective	• Values separable from facts • Science should not be subject to preconceptions (unbiased, impartial) • Science and scientists can and should be value-free
Independent	• Independent from subject, values, moral and political commitments, and environment (disinterested observer) • Judged on academic grounds; no reflection on individual
Reducible	• Deducible from the smallest number of possible axioms • Search for laws and law-like generalizations (ideal universal) • Largest amount of information with least effort (elegant)
Heuristic	• Builds on knowledge base (each addition contributes to enhanced understanding) • Continually testing and improving • Joined by theory
Methodological	• Accepted procedures for observing phenomena • Importance of observation, data, and evidence • Rigorous (precise), reliable, and standardized methods of investigation • Preference for quantitative results and experimental methods (most satisfactory form of evidence) • Reliability enhanced when multiple methods applied
Technological	• Reciprocal relationship between science and technology • Great advances in sciences often related to new tools • Omnipresence in science of machines, instruments, and experimental setups
Prone to positivism and scientism	• Science preferred source of knowledge (sometimes argued only valid source of knowledge)
Natural science model	• Physics as model for natural sciences • Natural sciences as model for social sciences • Scientific model for humanities • Scientific (normative) model for planning and decision making (e.g., IA, policy science, scientific management, scientific planning, scientific politics)
Explanatory	• Proper roles for science—measurement, observation, explanation, and prediction • No "ought" in science • Facilitates understanding • Conducive to decision making (knowledge base)
Verifiable	• Explicit assumptions and procedures • Traceable and replicable procedures • Possible to determine if correct (verifiable) or not (falsification) (possible to be weakly or strongly verifiable) • Prizes observation and measurement as primary means of explaining phenomena in comparable situations
Real	• Sometimes succeeds in stating the truth or a good approximation of • Knowledge is experienced based (meaning grounded in observation) • Objective world; can be observed and recorded in an objective manner
Collective	• A collective activity of discovery • Knowledge is shared (open, iterative) • Advanced by constructive discussion, analysis, and criticism (organized skepticism) • Must satisfy standards of peers
Pluralistic	• Multiple paradigms, theories, and concepts • Heterogeneous—many divisions within field • Multiple perspectives on definition, practice, and application of science
Consilient	• Underlying methodological unity • Fundamental laws and principles underlie every branch of learning (unity of knowledge) • Trend toward bridging of fields (interconnections, consistencies, middle ground, transcending concepts)
Certain	• Sufficient knowledge to measure and predict with accuracy • Manageable uncertainty
Causal	• Events have determinate causes • Causes precede events
Complex	• World viewed as a set of complex problems • Large number of variables and interrelationships • Still amenable to scientific methods
Beneficial or benign	• Can provide sound basis for decision making • Major contributions to society and environment

Sources: Barrow (1998), Cashmore (2004), Curtis and Epp (1999), Dawkins (1998), Erckmann (1986), Gower (1997), Greene (1999), Lemons and Brown (1990), Miller (1993), Orwell (2007), Patterson and Williams (1998), Pickering (1995), Porritt (2000), Rothman and Sudarshan (1998), Wilson (1998).

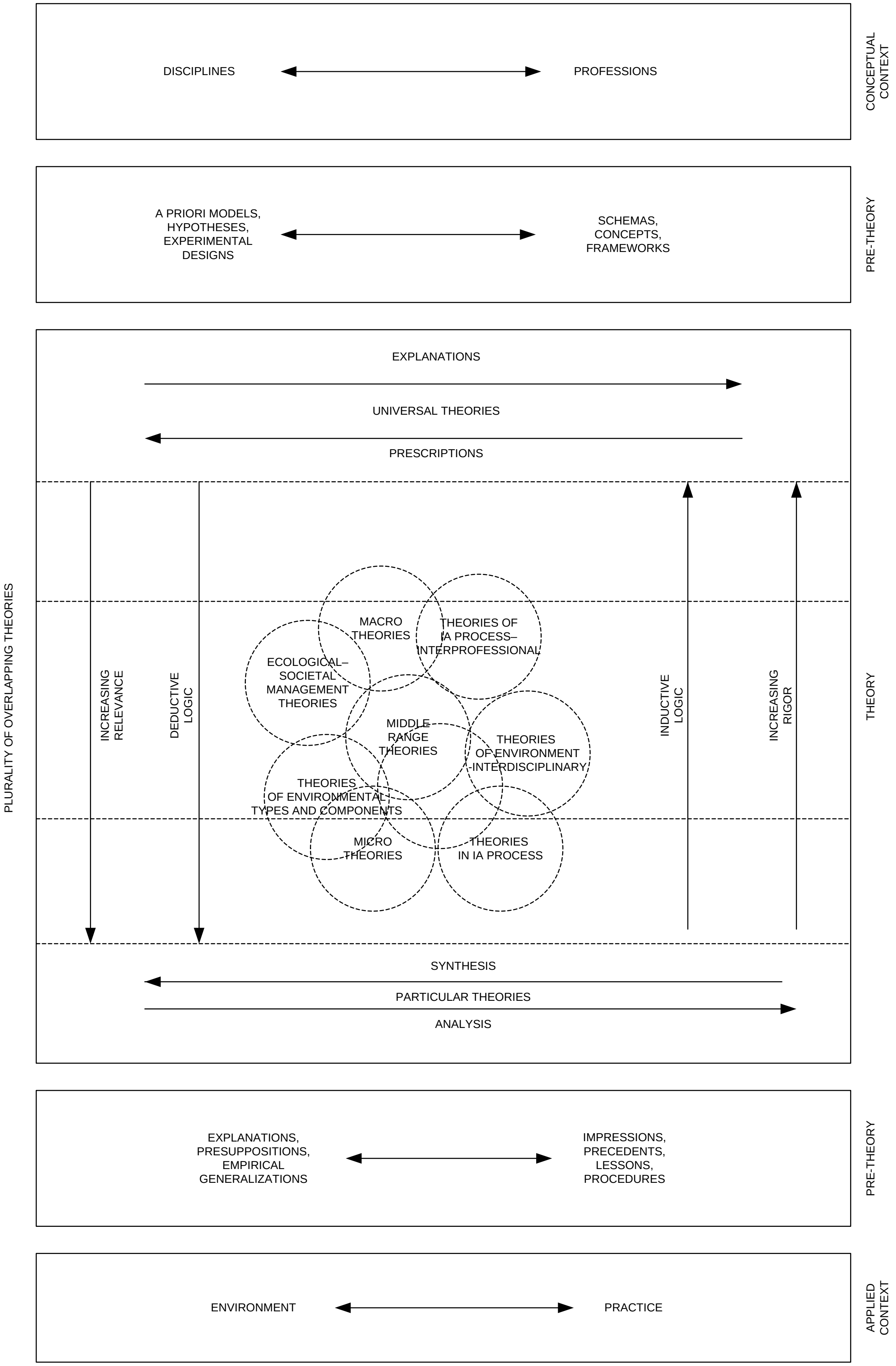

Figure 4.1 IA theory levels. Adapted from Lawrence (1997c).

if possible, in well-structured public interest arguments (Parkin, 1996).

4.4.2 Rigor Versus Relevance

The rigor versus relevance debate in IA is largely a false dichotomy. Natural and social scientific knowledge is a valuable resource for IA practitioners. It contributes to understanding and facilitates both significance interpretations and management actions (Healey, 1997). Appreciating the practical limits of IA practice, empirically adequate impact predictions are still conducive to better decision making and to better postapproval environmental management. Boundaries, assumptions, and models can and should be explicit and substantiated. Pilot studies and reviews of comparable proposals and environments can contribute to more accurate predictions and to more effective management actions. Monitoring can test the accuracy of impact predictions. Peer review can test methods and methods application. The substantive and methodological knowledge acquired through IA practice can be more broadly shared. Applied science, conducted under the auspices of IA practice, can be targeted to problems, opportunities, knowledge gaps, and uncertainties.

There can, moreover, be different degrees, standards, and forms of rigor. There are alternatives to analytical science (such as new or holistic science, chaos and complexity theory, regulatory or applied science), which, to varying degrees, relax and adapt the standards of analytical science. Rigor can be selectively applied. The issue then becomes which scientific standards are appropriate and reasonable, given the constraints and objectives of IA practice, rather than whether IA can or should be either rigorous or relevant. There is, however, a danger (some would say a "slippery slope") with selectively abandoning and adapting scientific standards. At some point one has ventured so far beyond the realm of applied science, that notwithstanding scientific "labels," what remains is no more than unsupported speculative thinking (Miller, 1993). Appreciating such risks, it still seems possible for IA practice to effectively blend both rigor and relevance. But any mixing of rigor and relevance will need to be carefully, systematically, and explicitly defined and substantiated.

4.4.3 Objectivity Versus Subjectivity

IA practice inevitably combines the objective and the subjective. Clearly, IA practitioners are not value-free. Much of IA practice is subjective. This does not mean that those advocating objectivity in science and in IA do not have valid points. Underlying the appeal for objectivity is a concern that if independence and transparency are simply abandoned, IA practitioners, documents, and procedures will be biased (often implicitly) against other stakeholders and against the environment whenever either conflicts with proponent interests. Some commentators will naturally conclude that such biases are inherent to IA. This is undoubtedly true to some degree, but bias can be reduced and environmental values can be applied.

Bias can be ameliorated if subjective judgments regarding assumptions, constraints, choice and application of methods and procedures, interpretations, and uncertainties are explicit, unambiguous, and substantiated (Beder, 1993; Rothman and Sudarshan, 1998; Mostert, 1996). Reports and methods can be peer reviewed. Professional codes of practice can be strictly adhered to and IA professionals can be accredited. Sometimes it is preferable if the proponent does not prepare some (e.g., interest groups generate own data) or all (e.g., IA reports and/or peer review reports prepared for the third party) IA documents (Beder, 1993). A tradition of openness and honesty in reporting can be fostered (Lee et al., 1992). Raw data and input reports can be made available (Beder, 1993). "Whistle blowers" can be encouraged and protected (Beder, 1993). All interested and affected parties can be freely and openly consulted and involved in interpretations and decisions (Rorty, 1991; Mostert, 1996).

Norms, values, and the interests of all parties can be systematically integrated into the IA process (Parkin, 1996; Mostert, 1996). Explicit environmental values, objectives, criteria, and ethical standards can be identified and applied (Mostert, 1996). Differences and tradeoffs among value-based positions can be systematically and explicitly explored and substantiated. The role of scientists and nonscientists in contributing to judgments will vary by IA process activity. Scientists could assume a greater role in impact analysis and monitoring. Nonscientists could take the lead in identifying issues and in impact evaluation and decision making (Morgan, 1998). This blending and blurring of the objective and the subjective does not mean that realism in science and in IA need be abandoned (Rorty, 1991). Although scientists and scientific methods are subjective (especially as applied in IA practice), this does not mean that there is no "objective truth." Predictions can be more or less accurate. Environmental management and IA practice can be more or less effective (Giere, 1999; Gower, 1997). What is required is that the objective, subjective, and objective/subjective elements of IA practice be transparent, substantiated, jointly determined (with interested and affected parties), and conducive to environmental enhancement.

4.4.4 Beneficial Versus Detrimental to Environment

IA is intended to benefit the environment or, at least minimize detrimental effects on the environment. Scientific IA approaches, in common with science, have been criticized for contributing to environmental degradation by reinforcing an aggressive, exploitive, reductionist, and arrogant worldview (Bowler, 1992; Porritt, 2000). The net result, it is argued, is a nonsustainable economic and social culture (O'Riordan, 1995).

IA practitioners need to guard against these negative tendencies. They can moderate or replace subtle assumptions regarding such matters as the levels of certainty and control, the beneficial links between science and technology, and the preeminence of scientists and scientific knowledge. The claims of holistic scientific theories regarding greater respect for the environment also can be scrutinized and tested (Bowler, 1992). Scientific principles and methods can be guided by and integrated with environmental ethical principles, imperatives, and standards (see Chapter 10).

4.4.5 Beneficial Versus Detrimental to Democracy

A common benefit attributed to IA is more open, transparent, informed, and democratic decision making. However, an overreliance on and uncritical acceptance of "expert" knowledge and interpretations (even in inherently subjective areas) can inhibit democratic debate (Bowler, 1992). Political values, perspectives, and interests can be implicitly subsumed within "objective expert" opinions. Science as expressed through IA can become a tool for political persuasion (Ozawa, 1991). The interests that sponsor applied IA research can distort priorities and findings.

These negative tendencies can be offset and ameliorated. The contributions of scientists can be acknowledged, without scientists acting like or being treated as all-knowing seers (Rorty, 1991). Community initiated research and interactions between scientists and the community can be encouraged (Henman, 1997). Other knowledge sources, such as traditional knowledge, can be integrated into decision making. Greater consideration can be given to subfields such as civic science (Porritt, 2000). An increased effort can be made to blend scientific IA practice with ethical democratic principles, perspectives, and imperatives (Bowler, 1992).

4.4.6 Espoused Versus Applied Science

The major discrepancy between the theory and practice of science, in an applied field such as IA, does not mean that the espoused model of science has nothing to offer IA practitioners. IA practice, except to its fiercest critics, is acknowledged to have generally improved over the past two decades. Arguably, improvements would have been greater had there been more of an effort to systematically define and build upon a core body of good practice, albeit with contextual adjustments. A systematic exploration of IA as applied (an inductive analysis) is likely to reveal patterns of good and bad IA process management. Although these patterns are largely at the level of pre-theory (as illustrated in Figure 4.1), they could lead over time (if tightly circumscribed within contextual limits) to micro-theory building. Similarly, IA concepts and frameworks for IA process management can be refined and tested in practice (i.e., a deductive analysis). Instead of choosing between espoused and applied science and IA, practitioners could iteratively move between the two in a progressive (albeit disjointed) process of knowledge accumulation, derivation, and application.

4.4.7 Predict and Control Versus Manage and Adapt

It is an overstatement to suggest that science as applied in IA is ill equipped to deal with risks and uncertainties or that complexity is the "order (or perhaps more appropriately 'disorder') of the day" in IA practice. Uncertainty can be partially addressed in IA by integrating techniques such as human health and ecological risk assessment. Gaps, uncertainties, and value assumptions, together with their implications, can be explicitly identified and explored (Lemons and Brown, 1990). Conservative assumptions can be applied. Multicriteria decision aids can facilitate the management of complex knowledge (Kain and Söderberg, 2008). Greater emphasis can be placed on minimizing type II errors (effects when none are predicted) (Reckhow, 1994). There could be situations where applying the precautionary principle is warranted (e.g., new technologies, processes or chemicals, catastrophic potential), where adaptive management is appropriate, or where elements of holistic and sustainability science are helpful.

Care should be taken not to overstate predictive and control limits or to abandon potentially valid and useful elements of analytical science. Holistic and sustainability science, moreover, may produce intriguing concepts and frameworks (Bond and Morrison-Saunders, 2009, 2011; Faber et al., 2010). But these concepts and frameworks may bear only a passing resemblance to reality (i.e., patterns imposed on rather than tested against or derived from the surrounding world) (Miller, 1993).

4.4.8 Analysis Versus Synthesis

Analysis is a central attribute of IA practice. Potentially affected components and functions of the environment must be determined. Impacts must be identified, predicted, interpreted, and managed. However, neither science nor IA end or should end with analysis. IA has always been integrative. Overall conclusions regarding both preferred alternatives and proposal acceptability must be reached to establish a sound decision-making basis. More attention is now devoted in IA theory and practice to interrelationships among environmental components, as reflected, for example, in ecological and socioeconomic models. Practical approaches have been formulated and applied for addressing cumulative effects; for considering economic, social, and biophysical interconnections (interdisciplinary rather than multidisciplinary analysis and synthesis increasingly under the umbrella of sustainability); and for integrating individual measures within management strategies (Caldwell, 1988). Also, as described in Chapter 2, greater attention is being devoted to interrelationships between IA, among IA types and levels, and with other forms of environmental management.

IA practice constraints necessitate professional judgment, adaptation, and creativity. Holistic and sustainability science could be especially useful when "wicked," trans-scientific, and "messy" problems must be managed (Kates, 2000; Miller, 1993). Analytical science could be better suited to situations, where problems can be readily circumscribed, where much is known, and where available methods appear adequate (Miller, 1993). For most IA problems, it could be better to maintain the analytic and holistic components in a "dramatic tension." Analytical methods and perspectives can be tempered by judgment, systems thinking, and a willingness to adapt and create. Holistic approaches need to be derived from or tested by empirical evidence obtained, where practical, by the judicious use of scientific methods and protocols.

4.4.9 Explanation Versus Prescription

IA is both explanatory (what effects are likely to occur?) and prescriptive (how are negative effects to be avoided and managed and positive effects to be enhanced?). The prescriptive IA role (i.e., to advance environmental values) is consistent with a management orientation. IA practice is not dissimilar to applied scientific research. Both are sponsored by government and industry and are directed toward social, environmental, and business purposes. IA-related research, although perhaps more tightly circumscribed, is still a form of scientific research. It can still, with appropriate qualifications, apply scientific principles and methods.

Many sociological, economic, and political science theories are normative. They extend beyond explanation. They also prescribe how institutions and society at large could more efficiently and effectively operate (Rorty, 1991). Applied fields such as management and planning also have combined the prescriptive and the explanatory under the umbrella of scientific planning and management, albeit with mixed results. IA can draw upon both the positive and negative lessons acquired in these fields.

4.4.10 Unified Science Versus a Plurality of Sciences

The divisions within science are considerable notwithstanding many integrative efforts. The same heterogeneous pattern of competing and overlapping theories and frameworks is repeated in applied fields such as planning, environmental management, and IA. A core body of IA knowledge and methods has yet to emerge more than tentatively. The debates surrounding whether science is, or should be, unified or pluralistic (including the middle-ground positions) indicate that defining good IA practice will not be a simple task. Being aware of the divisions within and among the natural and social sciences, as well as efforts to transcend divisions, could help interpret and place in context IA divisions and integrative initiatives.

An open and tolerant, albeit critical, posture to new theories, concepts, and frameworks is likely to be more conducive to insights and applications of value to IA practice than a strict application of analytical scientific protocols. Oftentimes, it will be necessary to select a mix of tools from both science and IA, appreciating their characteristics, strengths, limitations, and interconnections. These tools can then be adapted and applied to match proposal and environmental characteristics. No easy task! But perhaps one that is becoming less difficult as lessons and insights are increasingly emerging from IA quality and effectiveness analyses.

4.5 INSTITUTING A RIGOROUS IA PROCESS

4.5.1 Management at the Regulatory Level

The four jurisdictions (the United States, Canada, Europe, and Australia) have all instituted measures potentially conducive to greater IA rigor, as listed in Table 4.3. These measures illustrate a range of possible regulatory approaches to making IA practice more rigorous. Even collectively they fall far short of good practice standards. They do, however, represent a departure point for a more in-depth exploration of the subject.

They point to the value of an interdisciplinary approach and the need to document and substantiate methods and

Table 4.3 Positive and Negative Regulatory Level Examples Regarding IA Rigor

United States	Canada	Europe	Australia
(+) Emphasis on interdisciplinary approach, on analytic rather than encyclopedic documentation and rigorous evaluation of alternatives (+) Required to identify methods and sources (+) Extensive IA-related applied research and guidelines (e.g., CEA, mitigation and monitoring) (+) Presidential Memorandum on Scientific Integrity	(+) Power of Minister to issue guidelines and codes of practice (+) Power of Minister to establish research and advisory bodies (+) Requirement of follow-up program for verifying accuracy and determining effectiveness (+) Stronger agency role in promoting and monitoring compliance (+) Power to verify compliance or prevent noncompliance; includes orders, injunctions, prohibitions, and offenses (fines $100,000 to $400,000)	(+) Proposed Project Directive (PPD)—required to take into account current knowledge and methods of assessment (+) PPD—mandatory monitoring (to monitor significant adverse environmental effects, to assess implementation and effectiveness of mitigation and compensation measures, and to identify unforeseen adverse effects)	(+) Mitigation requirements (feasibility and effectiveness, proposed safeguards, statutory or policy basis, costs, environmental record of proponent) (+) Monitoring requirements (environmental management plan, outline, responsibilities, biodiversity monitoring) (+) Minister can require an environmental audit

Table 4.3 (*Continued*)

United States	Canada	Europe	Australia
(+) Oversight of IA system by combination of CEQ (advises President, resolves interagency disputes; policy and legislative recommendations, regulations, and guidelines; reviews agency procedures), EPA (review of environmental impacts, rating of adequacy of environmental impact statements, operational duties associated with EIS filings), and courts (interpretation and enforcement, largely procedural) (+) CEQ retrospective regulatory review plan; retrospective reviews of existing regulations (+) Final guidance specifying when there is a need to monitor environmental mitigation commitments (+) CEQ NEPA pilot program—solicitation to agencies and public to nominate projects employing innovative approaches to completing environmental reviews more efficiently and effectively; nomination and selection process (+) Information quality, objectivity, integrity, and utility guidance (US OMB, 2002) (+) Monitoring guidance (+) Annual NEPA reports (+) US DOE—quarterly report—lessons learned (−) Emphasis of procedure over substance (−) Limited application at strategic level	(+) EA Agency objects—promoting or conducting research on EA and development of EA techniques (including testing programs); promoting EA; promoting, monitoring, and facilitating compliance with Act; and promoting and monitoring EA quality (+) EA Agency may undertake studies or activities or conduct EA research; advises people re. EA and provides training opportunities, courses, and resources (+) History of sponsored applied research (+) Now legally enforceable decision statement (+) Cumulative effects provisions (+) Follow-up and CEA guidance (+) Quality Assurance Program (−) Research program has not yet been established; power to promote and conduct research does not mean that it will be re-established in a comparable form (−) Elimination of National Round Table on Economy and Environment (−) Removal of requirement to assess natural resource capacity (−) Issue of EA capability of Canadian Nuclear Safety Commission and National Energy Board (−) Issues of rigor of SEAs and large number of projects no longer subject to Act (−) Issues of maintenance of rigor with narrow definition of environment, narrow and selective definition of effects and alternatives and administrative/political discretion (−) Issue of maintenance of rigor when substitute or equivalent IAs are applied (−) Largely passive approach to regional studies (−) Lack of tiering	(+) PPD—required to identify monitoring parameters and duration (proportionate to nature, location, and size of project and significance of environmental effects) (+) PPD—periodic progress reports on implementation (+) PPD—required to describe forecasting methods and identify main uncertainties (+) PPD—competent authority to verify up-to-date information re. mitigation (+) PPD—requirement that reports prepared by or verified by competent and accredited experts (+) PPD – broad definition of environment and effects (+) PPD—requirement to address accumulation of impacts and reasonable alternatives (+) History of extensive applied research and a diverse array of quality and effectiveness reviews (+) Quality requirement for SEA Directive (+) SEA Directive—required monitoring (+) Oversight of IA systems provided by a combination of boards, courts, auditors, and independent effectiveness reviews (−) PPD—uncertain whether quality enhancement efforts consistent with time limits (−) History of considerable variability in IA quality and effectiveness	(+) Auditor General undertakes annual compliance audits (Auditor General 2002–2003) (+) Scientific advice provided through the Threatened Species Committee, the Biological Diversity Advisory Committee, and the Australian Heritage Committee (+) Planned National Centre for Cooperation on Environment and Development (to provide neutral forum within which industry, scientists, NGOs, and governments can cooperate in developing environmental standards, guidelines, and procedures) (+) Annual internal operations reviews of the EPBC Act (±) Recommendation by independent review of the EPBC Act for establishment of an independent environment commission to advise government on project approvals, strategic assessments, bioregional plans, and other statutory decisions; government did not accept recommendation (+) Government agreed to publish reasons for significant decisions (+) Government agreed to bring together and rationalize compliance and enforcement powers and responses (+) Detailed provisions for identifying and monitoring biodiversity (+) Consultation draft on Environmental Offsets Policy (−) Public can only take court action on procedural grounds (−) Limited attention to social sciences and concerns

sources. They underscore the importance of systematically assessing alternatives, the value of scientific procedural standards (especially as part of mitigation and monitoring requirements), the need for cumulative effects assessment requirements, and the pivotal role of government-sponsored IA scientific policy direction. They illustrate the roles that applied research, effectiveness reviews, pilot projects, training, and guidelines can assume in raising the level of IA practice. They demonstrate the potential benefits of professional accreditation requirements for individuals and organizations preparing and reviewing IAs, of independent oversight of IA legislation and regulatory compliance (including the potential for substantive legal challenges), of independent scientific advisory bodies, and of forums to facilitate collaboration between scientists and nonscientists. They point to the need to ensure and maintain scientific and technical integrity and capability, to broadly define the environment and effects, and to require the consideration of current knowledge (scientific and traditional) and good practice standards. They demonstrate the need to fully describe and substantiate forecasting methods; to explicitly identify uncertainties and related implications; to ensure that the basis for interpretations and decisions is open, transparent, and substantiated; and to systematically address interconnections among IA levels and between procedural and substantive environmental requirements.

The consistent identification and application of these types of principles and measures at the regulatory level could establish a foundation for a greater emphasis on sound science in IA practice. There are dangers when extending beyond general science-related principles and requirements, especially when seeking to integrate complex and sometimes conflicting social scientific protocols and suggested practice-based standards. Even the general scientific principles already incorporated into IA requirements are debatable and can be interpreted in multiple ways. It is essential to proceed with caution when instituting science-based IA requirements. It would be easy to fall into the trap of insisting on science-based requirements—requirements which are hotly debated in science, and which could constrain as much as benefit IA practice. A more flexible, performance-based approach could capitalize on the benefits of science while appreciating its limits for applied fields such as IA.

4.5.2 Management at the Applied Level

Figure 4.2 is an example of a rigorous IA process. Figure 4.2 and the process description that follows incorporate many scientific IA elements. IA process managers and participants can "pick and choose" relevant or appropriate elements. A rigorous IA process treats IA as an experiment. Predictions are hypotheses to be tested. The process is driven by independent, skilled, and qualified natural and social scientists. The scientists strive to ensure a rigorous, objective, and open process consistent with scientific principles and protocols. Scientific findings and interpretations are assumed to provide a sound decision-making basis.

Start-up The start-up to a rigorous IA process involves several, highly interrelated activities. The problem or opportunity to be addressed must be determined. Objectives, which represent the purpose of the experiment, must be formulated. Constraints and assumptions for bounding the experiment need to be established. It is necessary to identify the initial proposal characteristics that trigger the process. Preliminary methods for collecting, analyzing, integrating, and interpreting data must be identified. The need, an extension of the problem or opportunity, must be determined. The appropriate aspects of the context must be identified. Initial hypotheses, the preliminary alternative explanations suitable for testing, must be formulated. The experimental design, a research program for testing the hypotheses, must be prepared.

Experimental design principles are incorporated, where practical, into the rigorous IA process. Initial hypotheses of interest are formulated. The hypotheses are explanations of the likelihood and magnitude of potential impacts. Hypotheses are formulated for alternative proposal characteristics (options including the null hypothesis) and for alternative impact predictions for the proposal. The experiment is designed to suit the context, to achieve the objectives, and to operate within the constraints and assumptions. Graphical and statistical testing procedures using appropriate sampling frames support the analyses and the interpretations. The experiment is designed to minimize both type I (concluding that there are effects when none exist) and type II (concluding there are no effects where effects have occurred) errors.

Constraints (e.g., limits to knowledge) and assumptions (e.g., temporal and spatial boundaries, values) are explicit and substantiated. The study design addresses the implications of uncertainties and of contextual factors. A high level of rigor (the experimental methods and test protocols of analytical science) is applied when cause–effect relationships are simple and clearly structured. A lower level of rigor (more selective and superficial quasiexperimental and judgmental activities) is applied for more complex, larger scale, longer time horizon cases characterized by high levels of variability and low levels of predictability and control (Patterson and Williams, 1998; Beanlands and Duinker, 1983).

Multiple scientifically defensible methods structure the data collection and analysis, link and integrate impact predictions, and facilitate interactions among scientists (Bird, 1998). The methods are reliable and consistent (over a range of spatial and temporal scales). The startup activities are progressively refined as new data are incorporated into the IA process.

Analysis The analysis is highly structured and guided by explicit theoretical models (Lima and Marques, 2005). Multiple, reliable, and preferable precise environmental

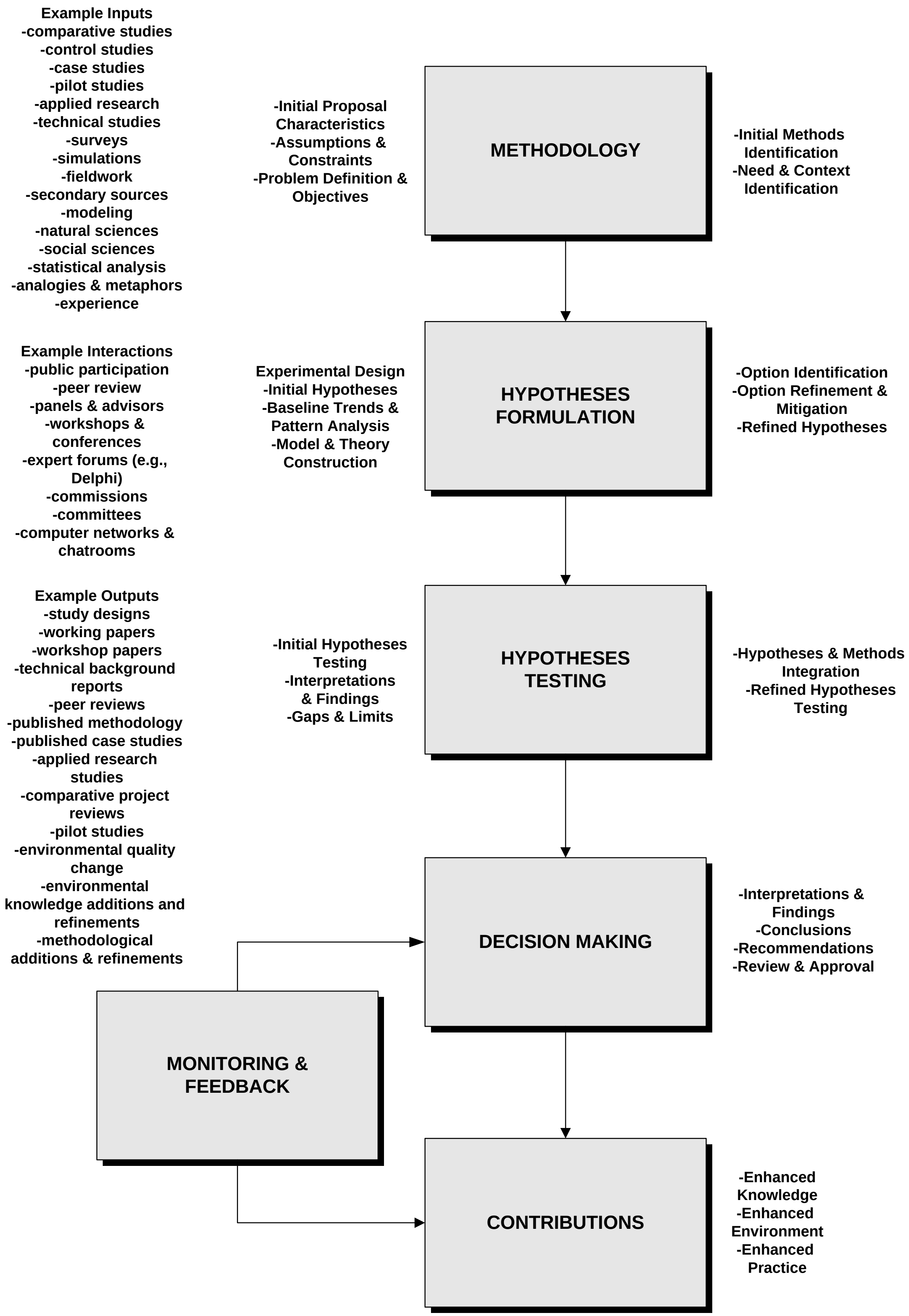

Figure 4.2 Example of a rigorous IA process. Adapted from Lawrence (2005a).

and social criteria and indicators are selected—criteria and indicators that can reveal (ideally statistically significant) changes in ecological and socioeconomic conditions. The level of detail (e.g., individual organisms, species, populations, communities) at which change occurs and can be reliably detected and predicted is carefully selected (Beanlands and Duinker, 1983). The analysis identifies and focuses on sensitive and significant social, economic, and ecological components, processes, and functions. Historical and emerging cumulative effects are identified (Cashmore, 2004).

Data, which can be readily aggregated or disaggregated, are collected over a range of temporal and spatial scales. Ideally, the IA database naturally extends from regional social, economic, and ecological indicators. The regional and greater statistics establish a context for subsequent impact interpretations. The baseline analysis is dynamic (trends and patterns over time and space) and conducive to the prediction and management of cumulative effects and systems level understanding (Seitz et al., 2011). The data are suitable for testing impact prediction accuracy.

Testable hypotheses are refined based on insights obtained from the baseline analyses. Predictions or implications are deduced for each competing hypothesis (Curtis and Epp, 1999; Greig and Duinker, 2011). A premium is placed on predictive precision (especially predictions that are easiest to test by observation and experimentation) and causal hypotheses (correlations between two kinds of events) (Bird, 1998; Wilson, 1998). Causal networks are identified and traced (Lord, 2011; Perdicoúlis and Glasson, 2006; Perdicoúlis et al., 2007). Predictions are first likely to be broad approximations. They are refined as more detailed data are integrated into the analysis (Greene, 1999). The object or process being studied is separated from its context to control confounding variables (Miller, 1993). Predictions address the magnitude, frequency, extent, and likelihood of potential effects. The bases for predictions are explicit.

Synthesis Interrelationships among environmental components and among potential impacts are addressed through models and occasionally preliminary theories. Multiple model types (conceptual, mathematical, physical, biological, social, economic, human health, and ecological risk) are applied. The models convey a systems level perspective on natural and socioeconomic conditions and provide a framework for predicting changes, including cumulative effects. They also are useful for testing options and mitigation methods (alternative hypotheses).

The models are derived from baseline spatial and temporal patterns and trends and from reviews of comparable, control, and pilot studies. They also draw upon natural and social science literature. They focus on critical environmental components and interrelationships. The refined hypotheses, emerging from the model and theory construction exercises, trace webs of causal connections beginning from the proposal, extending through various levels of direct and indirect effects, and ending with systems level effects. The models and theories are described and justified.

Models, theories, and hypotheses initially tend to be narrowly defined, generally within individual disciplines. A second round of model and theory building is usually necessary to address interconnections among the models and theories. Ideally, integrated assessment models or overarching theories can be constructed (Ravetz, 1998; Greene, 1999; Bird, 1998). Interconnections across consistent and mutually supportive theories and models are preferred. More commonly, interconnections and inconsistencies are only partially and subjectively addressed (Rothman and Sudarshan, 1998).

Hypothesis Testing The real measure of a rigorous IA process occurs when the validity of alternative hypotheses, based on explicit theoretical models, are rigorously tested (Curtis and Epp, 1999; Rossou and Makan, 2007). Hypothesis testing involves collecting empirical evidence and then modeling environmental conditions. An interrupted time series design for hypothesis testing tends to be preferred. This entails periodic tests, measurements, and observations of relevant variables at equally spaced intervals. The proposal is introduced at a predetermined interval. Hypotheses are tested (falsified) both prior (using comparative, control, case, and pilot studies) and subsequent (through monitoring) to approval (Burdge, 2004; Petticrew et al., 2007).

Hypothesis testing applies to the impacts predicted for the proposed action and to the impacts that could result from options and mitigation measures. Options tend to be excluded where severe impacts are likely based on reliable impact predictions and where there is a high degree of uncertainty and potentially severe consequences. Option comparison relies on a combination of social and natural scientific (preferably quantitative) indicators and substantiated scientific interpretations.

Gaps, limits, and uncertainties are explicitly identified together with potential implications. Uncertainties can be considerable given the complexity of the phenomena and the time and resource limits usually inherent to IA practice. Consequently, there is a tendency to incorporate procedures and assumptions that minimize the likelihood of underestimating the incidence and severity of adverse impacts. These procedures are explored more fully in Chapter 11.

Interpretations Extensive use is made of statistical tests of significance to facilitate interpretations in rigorous IA processes. Interpretations are often influenced by uncertainties regarding data reliability, the potential for systemic bias and nonlinear relationships. Both quantitative and logical techniques are used to analyze the evidence and to reach judgments based on the weight of evidence.

Interpretation is the creative component of science. Scientific interpretations encompass both espoused (reliance on statistical and other quantitative analyses) and applied (a systematic, creative, and collective endeavor) dimensions.

In the latter case, the boundaries between scientific and nonscientific IA processes overlap.

Approvals and Postapprovals Scientific findings and interpretations provide the primary decision-making basis. A scientific experimental design guides and structures the monitoring and follow-up program. Monitoring tests the accuracy of impact predictions and the effectiveness of mitigation measures. It can facilitate the enhancement of environmental and IA quality (Burdett, 2008a; Noble and Storey, 2005). Monitoring data can lead to new and refined hypotheses that are, in turn, tested through further monitoring (Storey and Noble, 2005). Follow-up assesses the validity and effectiveness of experimental design features, data collection and analysis procedures, model design and application, interpretations, environmental outcomes, and the overall rigorous IA process (Burdett, 2008a; Fuggle, 2005a,b; Noble, 2009b; Persson and Nilsson, 2007). It also can enhance environmental monitoring. Results can be incorporated into regional environmental databases (Gachechiladze et al., 2009).

Inputs, Outputs, and Interactions A rigorous IA process is far from closed. It extends from and contributes to natural and social scientific knowledge (Brown, 1986; Greig and Duinker, 2011). Links between SEA/EIA and CEA are systematically explored (Gunn and Noble, 2011). It draws upon interdisciplinary knowledge and on the experiences and insights of applied research scientists and IA practitioners (Caldwell, 1988). Model construction and hypotheses testing (prior to approvals) requires the systematic use of comparative, control, case, and pilot studies. Knowledge gaps are addressed through targeted research. Baseline analyses apply such scientific tools as surveys, field investigations, modeling, and computer simulations (Barrow, 1998). Statistical analyses aid significance interpretations. Analogies and metaphors often help structure the analysis but need to be confirmed through experimentation (Rothman and Sudarshan, 1998).

A scientific IA process is a collective endeavor. A team of natural and social scientists manage the process and provide specialist environmental knowledge and methods. Other scientists are involved as government reviewers and as specialist advisors and peer reviewers. Peer reviewers can assess the correctness of procedures and the plausibility of findings and conclusions (Hirschmann, 1994). Interactions among scientists occur through committees, workshops, commissions, panels, expert forums, and gateway websites (Dannenberg et al., 2006; Swor and Canter, 2011). Links to the broader scientific community are maintained by circulating and publishing (where practical) research findings and by means of human and computer networks (Barrow, 1998). Broader agency, political, and public participation occurs prior to major decisions and in the review of documentary outputs. Knowledge is freely exchanged and transferred (Sheate and Partidário, 2010). The public and politicians assume a more prominent role in defining the problem and objectives, in contributing to significance interpretations, in suggesting options, in participating in follow-up, and in tempering and testing conclusions and recommendations (Devlin, 2011; Hunsberger et al., 2005).

Rigorous IA processes tend to have numerous interim documentary outputs (e.g., study designs, working papers, applied research studies, pilot studies, technical reports, comparable project reviews, workshop reports, background studies, peer reviews). The findings from scientific and technical support studies are fully integrated into core documentation. IA process documentation extends into postapproval with the preparation and circulation of monitoring results. Consistent with good scientific practice assumptions, methods, and findings are fully and fairly represented. They also are independently evaluated and subjected to rigorous criticism. A rigorous IA process is expected to add to the environmental and IA knowledge base, to maintain and enhance IA quality and effectiveness, and to contribute to environmental protection and enhancement (Donnelly et al., 2008; João, 2007).

Adaptations and Variations There are multiple perspectives in the scientific community regarding what constitutes "the" scientific method or indeed whether a plurality of methods is both necessary and desirable. The same is the case for a rigorous IA process. The process, described in the preceding subsections, largely conforms to the tenets of analytical science. Several important modifications have been made, most notably the greater emphasis on integration, the infusion of environmental values and objectives, and the direct links to decision making.

This process could be tempered or replaced by, for example, a holistic, a management, a complexity, an applied, a conservation, or a civic scientific IA process (Cashmore, 2004; Levins, 2003). A rigorous IA process also varies by IA level and type (Nilsson et al., 2009) (see Section 4.5.4). These other rigorous IA processes are treated here as tempering considerations or at best variations rather than as alternatives to the analytical model. This is partly because they are not nearly as fully developed and have been applied to a much more limited extent. Also, if viewed as a replacement to analytical science, there is the question of whether the process that emerges is still primarily "scientific" in orientation.

Viewed solely in a tempering capacity, holistic or new science points to the value of creativity, intuition, imagination, judgment, and flexibility and to the potential roles of multiple trans-scientific and systems perspectives and frameworks (Miller, 1993; Porritt, 2000). Management science demonstrates the need to place IA-related science more firmly in the context of decision-making priorities, requirements, and limits. Complexity science and the precautionary principle underscore the central position of uncertainty, especially in applied fields such as IA (Levins, 2003; Tickner, 2003e). It also systematically addresses the implications of uncertainty for the ability to predict and manage and for the design and adaptation of planning processes and organizations (Patterson and Williams, 1998; Rothman and Sudarshan, 1998). Civic science points to the need for and value of having interested and affected members of the public assuming a less peripheral role in the IA process. Civic science argues that the public should assume a valuable role in shaping the process and in contributing to such tasks as data collection, analysis, and interpretation (Henman, 1997; Ozawa, 1991; Porritt, 2000).

The multiparadigm view of science is intriguing. It forms part of the foundation for the structure of this book. It offers many insights regarding potential ways of linking, integrating, and transcending multiple, overlapping models within and among disciplines and fields of practice. It also clearly demonstrates the many pitfalls and potential losses associated with pushing the integration process too far. To avoid repetition, the themes and insights derived from an exploration of multiparadigm approaches to science have been incorporated into Chapter 12 (which addresses interrelationships among the IA processes).

4.5.3 Theory Building

Science and IA have a complex relationship, as illustrated in Figure 4.3. The IA process described is driven, framed, and structured by analytical science. However, because of the practical realities of an applied field such as IA, its aspirations, to be realistic, are more in the nature of pre-theory—aspiring toward particular and middle-range theory building. Also, scientific IA processes and practices are tempered to integrate the relative, the relevant, the subjective, the practical, the applied, contextual adaptations, the need to connect and transcend disciplines and decision-making levels, the prescriptive, and the multiperspective nature of IA related practice. SEA and EIA practice (including the overlapping areas that encompass integrated IA, CEA, and various forms of tiered planning and decision making) are both extended and refined (by more technical and scientifically oriented substantive IA types), and challenged and restructured (by more transformative, political, holistic, and collaborative IA types). Individually SEA and EIA process types can, depending on the type or type combination, refine/reinforce or challenge/restructure rigorous IA practice. Theories, frameworks, and models derived from the natural and social sciences tend to extend and refine SEA and EIA science-based approaches. More integrative forms of science, such as sustainability science, are more prone to challenge and restructure IA theory and practice. Follow-up and auditing, as detailed in Section 4.6, assumes a critical role in applying, testing, adapting, enhancing, refining, and sharing scientific IA practice.

Numerous general measures are possible to facilitate IA theory building. A scientific integrity policy can be instituted. Good practice guidance can be provided regarding best practical science and traditional knowledge. Guidance materials can be based on monitoring and auditing outcomes. Greater emphasis can be placed on environmental outcomes and cumulative effects, and on uncertainty, complexity, surprise, and whole systems. Infrastructure enhancements can be instituted, such as the performance tracking of IA documents, a national IA database for the public and practitioners, and annual state-of-environment reporting (which integrates monitoring outcomes). Comparative studies of IA legislation, regulations, institutional arrangements, and context can be sponsored. IA performance evaluation can be linked to research. IA knowledge and experiences can be shared. Best practical science standards can be applied. Greater use can be made of comparative studies.

A proactive effort can be made to contribute to IA theory building and good practices. Care can be taken to delineate the rationale, limitations and implications of methods, to apply appropriate scales, time horizons, and level of detail, and to make appropriate contextual adjustments. IA theory-building efforts are facilitated if the environment and effects are broadly defined, if interconnections among IA types and cumulative effects receive particular attention, if assessment studies and applied IA research are broadly available, and if a proactive effort is made to connect and transcend organizational barriers. Drawing upon and contributing to interdisciplinary science, the integration of citizen knowledge and the maximizing of learning potential should be priorities. Knowledge limits should be explicitly acknowledged, the roles and responsibilities of specialists and advisors should be specified, key references should be integrated, the effectiveness of substantive outcomes should be assessed, and a clear theoretical framework should be applied.

4.5.4 Variations by IA Type

Table 4.4 details examples of theory-building possibilities for different IA levels (SEA and project EIA) and for various substantive IA types (SA, EcIA, SIA, and HIA). In general terms, these measures address such matters as scientific integrity, sponsored research and research priorities, methodological standards and protocols, good practice guidance, knowledge sharing and contribution procedures, supportive databases, study scope and design, transparent and substantiated methodology, connections to related bodies of knowledge, and contextual adaptations.

Strategic Environmental Assessment (SEA) At the SEA level, effective theory building starts from a particular need to test the suitability and effectiveness of alternative SEA institutional arrangements and approaches, to demonstrate the added value of SEA, and to forge more effective links between SEA and policy/plan making and decision making. It requires seeking a better understanding of organizational and institutional procedures and barriers and how they might be influenced and altered, demonstrating tangible contributions to environmental enhancement, and enhancing the level of SEA practice and the credibility of SEA

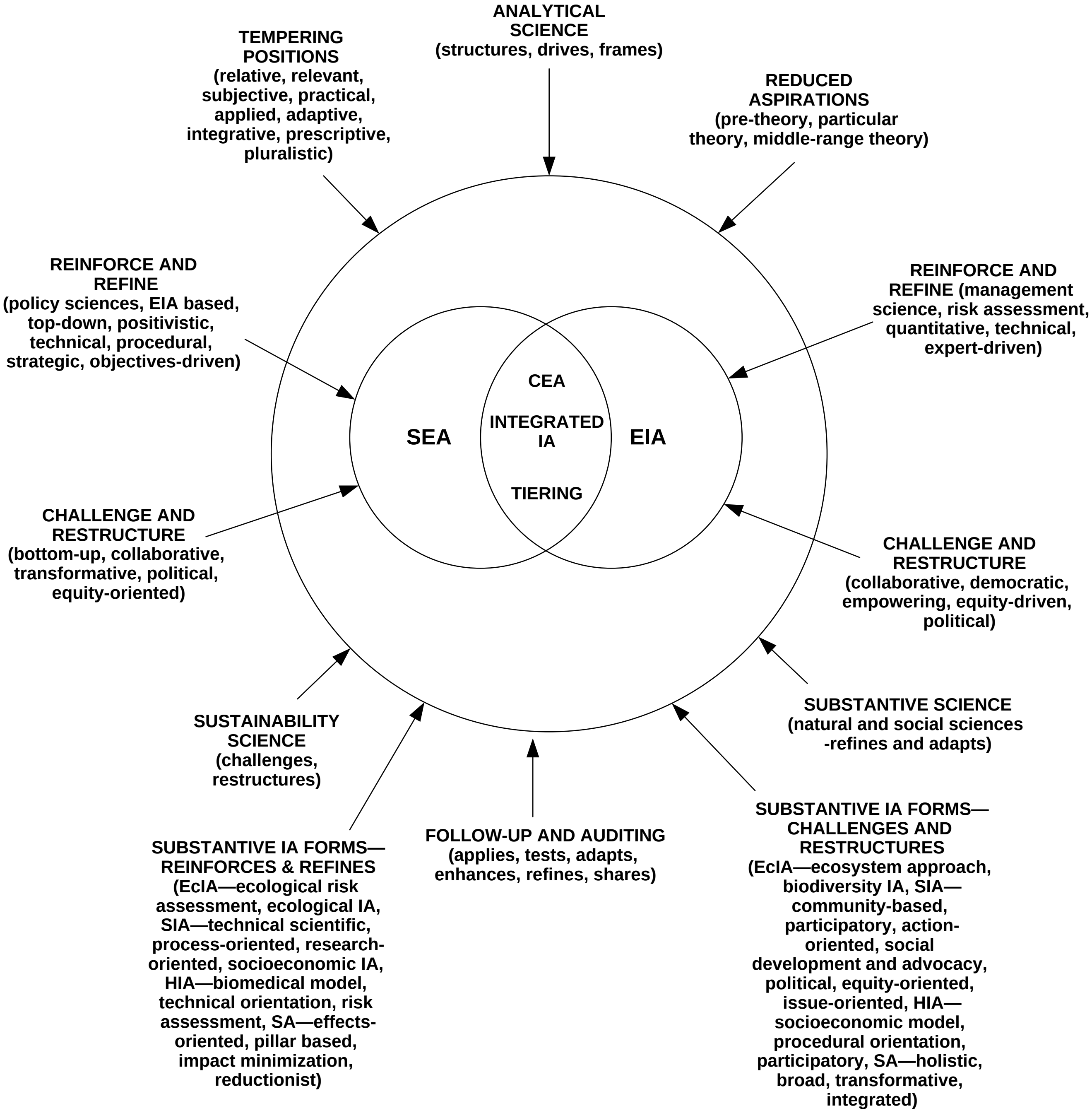

Figure 4.3 Science and IA.

practitioners. It also involves better differentiating between project-level and SEA good practices; distinguishing SEA good practices for and across varying decision-making levels, sectors and settings; more effectively integrating cumulative effects and manage uncertainties; and facilitating organizational and institutional learning, knowledge exchange, and capacity building.

Environmental Impact Assessment (EIA) At the project EIA level, theory building entails establishing more effective links between the scientific and EIA communities and knowledge systems; making more effective use (with appropriate adaptations) of scientific methods, models, and standards; enhancing the role of environmental databases in supporting EIA and the contribution of EIA to such systems; and more systematically undertaking EIA-related research targeted at key knowledge gaps and uncertainties. It also seeks to raise the quality of scientific practice and practitioners in EIA (especially regarding follow-up and auditing procedures); to more effectively test and refine EIA models,

Table 4.4 Rigorous IA Practice Characteristics by IA Type

Rigorous SA Practice	Rigorous SEA Practice	Rigorous EIA Practice
Clearly and strictly defines sustainability and sustainability purposes, extends time horizons, broadens spatial horizons, and includes positive and negative effects Provides guidance regarding means of integrating sustainability into each IA activity Links to sustainability priorities and targets at all levels—international, national, regional, and local—specifies what to sustain, why, and progress toward sustainability Focuses on links to sustainability objectives and reference points, genuinely sustainable decision making and environmental outcomes, equity concerns, and barriers to sustainability integration and strategies for overcoming Seeks to institutionalize sustainability and contribute to sustainability capacity building Links to other sustainability plans, strategies, programs, objectives, and standards Registers SA professionals Sponsors research on approaches for integrating and transcending pillars and disciplines, sustainability research systems and science, and SA as a platform to facilitate knowledge exchange and transfer Adopts postnormal science approach (uncertain facts, value disputes, and urgent) and holistic and dynamic perspective (constant improvement) Is creative, adaptive, and precautionary Draws upon and contributes to sustainability research and interweaves positive and negative, ends and means, and limits and opportunities Avoids reductionist methods and integrates good practice SA principles and procedures	Provides guidance linking SEA to policy and plan making Provides guidance for testing the added value of SEA policy, plan or, program development and downstream assessment Focuses on proactive and integrative SEA approaches, analyzing how organizations and institutions function, assessing the quality and effectiveness of SEA outputs, facilitating uncertainty management and organizational learning, overcoming obstacles and pitfalls to SEA, and enhancing decision-making influence Institutes and refines SEA/EIA tiering system and multiscale and multidirectional analysis Contributes to SEA capacity building Registers SEA professionals Sponsors research on effectiveness of SEA legal frameworks and alternative SEA approaches, frameworks, and models in varying decision settings Undertakes case studies and methodological comparisons across a range of sectors, jurisdictions, and SEA levels Explores data issues and spatial and temporal scales differences and implications Seeks to strengthen and making science–policy links transparent Integrates SEA and CEA Institutes quality assurance checklists, facilitates SEA knowledge exchange and transfer, refines the SEA toolkit, and assesses differences between what should and did happen	Requires independent monitoring and auditing of implementation, compliance, and auditing Establishes realistic standards for quality of EIA scientific practice Focuses on substantive purposes, causal processes, and mitigation effectiveness Seeks more reliable science to better inform EIA, better science–politics links, enhanced scientific support outside EIA community by tapping into public pressure, and encouraging regulators and targeted research Institutes science advisory boards, research and centers of excellence, and environmental data clearinghouses Contributes to EIA capacity building Registers EIA professionals Sponsors research on more effective ways of integrating EIA and CEA Seeks to create, test, and refine predictive models Applies experimental design where practical Treats science roles as applied, experimental, and naturalistic Emphasizes sound methodology, evidence standards, and concise analysis Uses EIA to generate testable hypotheses and monitoring data Identifies, refines, and tests causal network analysis

Rigorous EcIA Practice	Rigorous SIA Practice	Rigorous HIA Practice
Incorporates ecological and biodiversity principles, concepts, and techniques Provides guidance regarding integration of ecological concerns into each IA activity and concerning ecosystem approach and biodiversity principles and practices Links to ecological priorities and targets at all levels—international, national, regional, and local	Includes social–psychological impacts and social responses to impacts Provides guidance regarding integration of social concerns into each IA activity, social changes at micro (e.g., individual, family, business) and macro (community) scales, and social change processes and social impacts	Broadly defines health and health determinants Provides guidance regarding integration of health concerns into each IA activity; data types and sources for HIA application, HIA methods, models, and follow-up, indigenous community research in HIA, and HIA follow-up

Table 4.4 (*Continued*)

Rigorous EcIA Practice	Rigorous SIA Practice	Rigorous HIA Practice
Focuses on potential damage to and protection of unique, endemic, threatened, and declining species, habitats and ecosystems, holistic biotype/ ecological function approaches, ecological sustainability, biodiversity and ecological follow-up, and barriers to ecological integration and strategies for overcoming Seeks to institutionalize EcIA Links to ecological risk assessment and to conservation and ecological planning and management Supplements holistic databases to systematically address ecosystem functions and ecological connections and networks Facilitates biodiversity partnerships and information networks and EcIA training and capacity building Registers EcIA professionals Sponsors research to address refinements to ecological scoping and follow-up frameworks and methods, enhancements to biodiversity and EcIA impact prediction models and tools, and habitat loss and fragmentation methods Explicitly recognizes natural system uncertainties and complexities, fully represents ecological levels and integrates biodiversity models and frameworks Defines EcIA roles at SEA and project EIA levels Draws upon and contributes to GIS modeling, biodiversity indicator, and ecosystem process research Promotes awareness and analysis of ecological effects Integrates good practice EcIA principles and procedures	Focuses on social sustainability, barriers to social integration and strategies for overcoming, means of combining and integrating SIA methods and perspectives, culturally appropriate social benefits, opportunities and capital enhancement, and social justice and distribution of effects (especially for most vulnerable) Seeks to institutionalize SIA Incorporates mechanisms for facilitating community empowerment Contributes to SIA training and capacity building Registers SIA professionals Links to social research systems Links to other social plans, strategies, programs, objectives, and standards Sponsors research on SIA approaches and methods adapted by proposal, IA and context type, and means of integrating SIA and indigenous knowledge, perspectives, rights, and positions Seeks to base SIA on sound and replicable scientific methods and concepts Adopts hypothesis testing approach for follow-up, where appropriate Ensures sound understanding of social and cultural context Defines SIA roles at SEA and project EIA levels Promotes awareness and analysis of social effects Integrates good practice SIA principles and procedures	Focuses on health sustainability, barriers to health integration and strategies for overcoming, the effective blending of health and social sciences for addressing complex causal links, especially health determinants, HIA and decision-making links, more robust magnitude and distribution prediction methods, and more effective approaches for engaging health authorities and experts Seeks to institutionalize HIA Applies a longitudinal demographic surveillance system to facilitate health monitoring and evaluation Provides institutional support for HIA Links to other health plans, strategies, programs, objectives, and standards Contributes to HIA training and capacity building Registers HIA professionals Defines HIA roles at SEA and project EIA levels Promotes awareness and analysis of health effects Seeks to strengthen scientific evidence in support of causal links Integrates good practice HIA principles and procedures Fully engages health professionals and experts Fully integrates community health perspectives and knowledge Refines methods application based on follow-up of both decision-making influence and health outcomes

Sources: Alshuwaikhat (2005), Ahmadvand and Karami (2009), Barth and Fuder (2002), Becker et al. (2005), Bhatia (2007), Bhatia and Seto (2011), Bhatia et al. (2010), Bond (2010), Bond and Morrison-Saunders (2009, 2011), Burdge (2003a,b, Burdge (2004), Cashmore (2004), Chaker et al. (2006), Cherp et al. (2011), Cranor (2003), Dannenberg et al. (2006), De Ridder et al. (2010), Dimento and Ingram (2005), Doelle and Sinclair (2006), Donnelly et al. (2008), Dovers (2005), Duffy (2008), Elliott et al. (2004), Égré and Senécal (2003), Faber et al. (2010), Fischer (2003, 2005, 2007b), Fischer et al. (2010), Forsyth et al. (2010), Gasparatus et al. (2007), Gachechiladze et al. (2009), Geneletti (2003), Gibson (2006a,b, Gibson,2011), Gontier et al. (2006), Govender et al. (2006), Greig and Duinker (2011), Grinde and Khare (2008), Gunn and Noble (2011), ten Hallers-Tjabbes (2003), Hanna (2009a), Hansel and Aylin (2003), Hansen and Wolff (2011), Harris-Roxas and Harris (2011), Hermans and Knippenberg (2006), Hunsberger et al. (2005), IAIA (2005, undated b), ICPGSIA (2003), IEEM (2006), Jha-Thakur et al. (2009), João (2007), João and Mclauchlan (2011), Jones and Slinn (2008), Kain and Söderberg (2008), Kates (2000), Kemm (2005), Kemm and Parry (2004a,b), Ketelsen (2003), Khera and Kumar (2010), Kobus (2005), Kumagai et al. (2006), Kwiatkowski (2011), Kwiatkowski et al. (2009), Lane et al.(2003), Lavallée and André (2005), Levins (2003), Lima and Marques (2005), Lobos and Partidário (2010), Lord (2011), Mandelik et al. (2005), McCaig (2005), Moles et al. (2008), Morrison-Saunders and Bailey (2003), Nilsson et al. (2009), Noble (2009a,b), Noble and Bronson (2006), Noble and Storey (2005), O'Faircheallaigh (2009), Partidário (2007), Partidário and Arts (2005), Perdicoúlis and Glasson (2006, 2009), Perdicoúlis et al. (2007), Persson and Nilsson (2007), Petticrew et al. (2004), Petticrew et al. (2007), Pisani and Sandham (2006), Pope and Grace (2006), Pope and Klass (2010), Quigley and Taylor (2003), Retief et al. (2008), Retief (2007a,b), Rossou and Makan (2007), Rotmans (2006), Rowan and Streather (2011), Runhaar (2009), Sadler (2005b), Scanlon and Davis (2011), Schirmer (2011), Seidler and Bawa (2003), Sheate and Partidário (2010), Seitz et al. (2011), Shepherd (2008), Sherrington (2005), Singh et al. (2009), Slootweg (2005), Söderman and Saarela (2010), Storey and Jones (2003), Storey and Noble (2005), Taylor et al. (2004), Thérivel et al. (2009), Tickner (2003c,e), Tzoumis (2007), US EPA (2011), Weiland (2010), Winkler et al. (2011), US EPA (2011), Utzinger et al. (2005), Vanclay (2010), Wlodarczyk and Tennyson (2003), Zhu et al. (2010), Ziller and Phibbs (2003).

methods, and mitigation measures; and to more effectively integrate substantive environmental concerns and priorities, such as cumulative effects and climate change, in a manner that results in tangible improvements in environmental quality.

Substantive IA Types Theory-building priorities, for the explicitly substantive forms of IA (SA, EcIA, SIA, HIA), only partially overlap with those identified for SEA and project-level EIA. Collectively, these IA types are concerned with more effective links across disciplines, decision-making levels, and IA types without compromising the integrity and ethical and disciplinary standards of individual specialties, with narrowing the gulf between theory and practice, with more effectively managing uncertainty and complexity, and with more effectively operating within political/administrative decision-making systems and IA institutional structures. They also strive to enhance the integration of theory and an appropriate mix of methods, models, and frameworks while still allowing for contextual variations; to forge better links to, contributions to, and integration with broader knowledge systems; to facilitate an enhanced understanding of interactions between human activities and the environment; and to make a tangible contribution to the enhanced state of the environment.

Sustainability Assessment (SA) SA theory building seeks to interconnect and transcend individual disciplinary sciences. This necessitates redefining IA practice, at the regulatory and applied levels, with clear sustainability objectives and benchmarks, broadened spatial and temporal boundaries, a broader definition of environment and effects, a greater focus on equity concerns, and a concerted effort to integrate sustainability into each IA activity. Tangible progress toward sustainability, as demonstrated through decision making and environmental outcomes, is required. Organizational reforms conducive to sustainability capacity building are essential. Effective links to related sustainability initiatives and objectives, to sustainability research systems, and among organizations and individuals with sustainability knowledge must be established. Enhancing the status of SA professionals would be helpful. A particular effort needs to be made to transcend individual disciplinary and other boundaries, to employ a holistic and dynamic perspective, to anticipate and more effectively manage risks and uncertainties, to generate creative mutually beneficial opportunities, and to incorporate and contribute to sustainability theory and good practices.

Ecological Impact Assessment (EcIA) EcIA theory building can be more effectively framed by regulatory requirements and guidelines that fully and systematically integrate ecological and biodiversity principles, concepts, objectives, and methods. A particular effort needs to be made to protect rare and highly valued species, habitats, and ecosystems; to make effective use of ecological and biodiversity techniques (especially as part of follow-up); to overcome barriers to the integration of ecological concerns; and to facilitate the achievement of ecological sustainability. An ecological perspective and sensitivity to biodiversity concerns must be integral to public and private organizational and institutional decision making if EcIA theory building is to be effective. This means holistic ecological databases; effective links to related fields of theory and practice; biodiversity and ecological partnerships and networks; and EcIA training, capacity building, and certification. Effective applied ecological and biodiversity research regarding such matters as ecological scoping, prediction, follow up, and uncertainty management also is essential. In addition, good EcIA practices, differentiated by SEA and project level and by ecological level, must be consistently tested, refined, applied and, wherever practical, supplemented.

Social Impact Assessment (SIA) Effective SIA theory building requires institutional arrangements (requirements, guidelines, infrastructure) that broadly define social impacts (e.g., social, cultural, sociopsychological, heritage); address social impacts at micro and macro levels; and encompass social change processes, social impacts, social responses to impacts, social justice, and ultimately social sustainability. Particular attention needs to be devoted to the distribution of social effects (especially regarding effects on the most vulnerable); to the realization of social benefits, opportunities, and capital enhancement; and to the facilitation of community empowerment. The organizational and institutional barriers to effective SIA theory building are considerable. Some of the steps needed to ameliorate those constraints include an ongoing effort to combine and integrate SIA methods and perspectives; better links to social research systems and to related social interventions, SIA training, capacity building, and the certification of SIA professionals; the systematic differentiation of SIA approaches by proposal, IA, and context type; the more effective integration of community and indigenous perspectives and knowledge; and the adaptation, application, and extension of good practice SIA principles and procedures—especially with regard to follow-up.

Health Impact Assessment (HIA) Effective HIA theory building is conditional on IA institutional arrangements that provide for a broad definition of health and health determinants; effective guidance regarding such matters as data types and sources; prediction methods, models, and follow-up; enhanced health data systems; strategies for more fully engaging health professionals and experts; links to related health initiatives; HIA training and capacity building; and the certification of HIA professionals. The HIA state of practice can be furthered by such theory-building initiatives as methodological refinements; additional effectiveness case studies; the integration of community health and indigenous perspectives and knowledge; and applied research regarding causal links, prediction methods, follow-up procedures, and decision-making influence. A particular effort is needed to remove barriers that impede the integration of health concerns into decision making, to better define HIA roles at the SEA and project EIA levels, and to further the cause of health sustainability.

4.6 CONTEMPORARY CHALLENGE—GOOD PRACTICE IA FOLLOW-UP

Good practice follow-up, as illustrated in Figure 4.4, draws upon a diverse array of regulatory and applied procedures and methods. It also necessitates clearly defined procedural

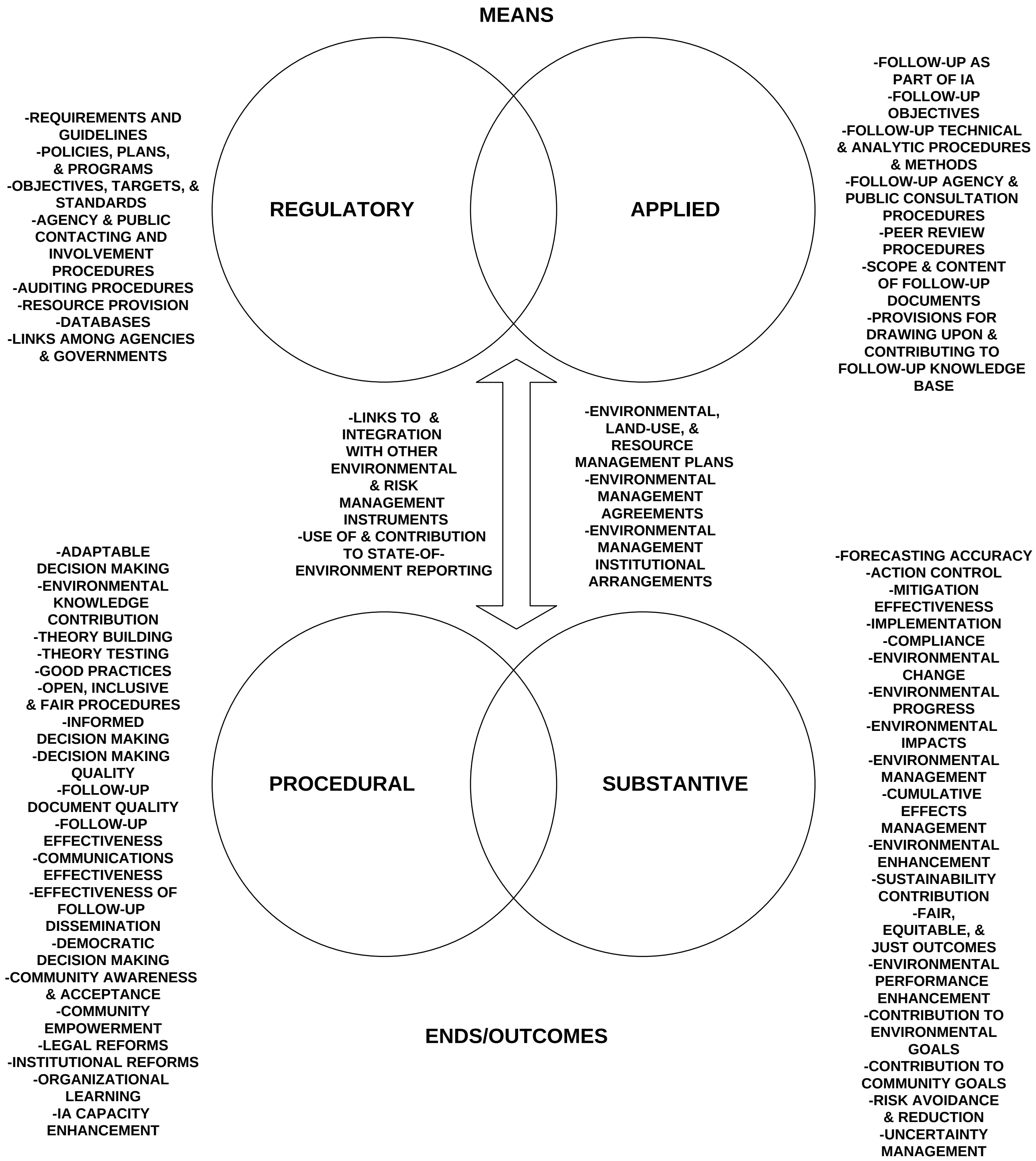

Figure 4.4 Examples of good practice follow-up.

and substantive objectives—objectives that are defined at the outset and tested for effectiveness throughout the course of implementation. These individual ends and means should be knit together into a coherent and fully substantiated impact management plan. The impact management plan, in turn, should draw upon and contribute to related environmental management instruments; state-of-the-environment reporting; and environmental, land-use, and resource management plans and strategies. IA follow-up, to be effective, must be framed within and formalized by action-forcing institutional arrangements and implementation mechanisms such as environmental management agreements.

The tendency has been to define follow-up narrowly (e.g., only biophysical impacts, only for the purpose of assessing forecasting accuracy and determining compliance and mitigation effectiveness). Good practice IA follow-up broadly defines the environment and effects, and encompasses a broad array of procedural and substantive objectives. Procedurally, IA follow-up can, for example, seek to ensure that decision making and decision-making documents are adaptable, fair, inclusive, transparent, and informative. Additionally, it can further legal and institutional reform; enhance the potential for fully substantiated and higher quality decisions; facilitate democratic decision making and community empowerment; contribute to IA capacity enhancement, organizational learning, and community awareness and acceptance; and assist in environmental and IA theory building and testing. In a substantive sense, in addition to assessing forecasting accuracy, compliance, and mitigation effectiveness, good practice IA follow-up can avoid and ameliorate adverse individual and cumulative environmental impacts; enhance the environmental performance of proposed actions; contribute to positive environmental change, community goals, environmental goals, and sustainability; reduce environmental risks and uncertainties; and increase the likelihood of just and equitable outcomes. Good practice IA follow-up clearly defines procedural and substantive objectives, adjusts objectives as needed through the course of implementation, and systematically tests if and the extent to which objectives are achieved.

Table 4.5 highlights a wide range of suggested IA follow-up good practices. The good practices encompass both the regulatory and applied levels. Good practice follow-up at the regulatory level includes possible measures addressed through requirements and guidance; the sponsorship of research and good practices; institutional reforms and practices; and the auditing of IA documents, procedures, and the overall IA system. Applied level IA follow-up good practices pertain to follow-up process design, the scope of the follow-up program, the analytical methods employed, consultative procedures, and external connections and theory building. To be effective, these individual measures need to be effectively integrated into a coherent and complementary set of follow-up institutional arrangements and applied objectives and procedures.

Table 4.5 Examples of Good IA Practices—Follow-up

Regulatory Level	Applied Level
Requirements and Guidance	*Process Design*
Require mitigation, follow-up, and reporting	Institute monitoring before approvals (baseline)
Require action and environmental monitoring	Design to suit proposed activities, potential effects, decision-making level, culture, and IA type
Require consideration of accidents, malfunctions, and natural disasters and risks (including climate change)	Identify and substantiate follow-up purpose, goals, and objectives, including clear commitments list
Require consideration of social, health, ecological, cumulative, transboundary, and sustainability effects	Identify follow-up roles, tasks, and responsibilities; change proponent must accept responsibility for implementing follow-up, and roles should be distinguished to avoid conflicts-of-interest
Require public and agency consultation	Ensure follow-up system is timely, adaptable, and action oriented
Require publication of follow-up results	Ensure actions effectively satisfy follow-up program goals
Require that decision making consider follow-up results	Evaluate, as applicable, policy, plan, program, and project performance; undertake necessary remedial actions
Require modifications to action based on monitoring results, where warranted	*Scope*
Require legally binding approval conditions; ensure enforceable	Identify and substantiate staged scope of follow-up (e.g., draft and final programs at varying levels of detail with provision for ongoing adjustments)
Require regular independent review of IA system (legislation, regulations, policies)	Sustain follow-up over entire life of activity (e.g., design, construction, operations, decommissioning)
Allow for compensation/environmental offsets	Broadly define environmental (physical, ecological, social, heritage, economic) effects
Stipulate duty of proponents to avoid and minimize harmful environmental effects	Monitor environmental quality, change, and progress
Permit legal appeals and provide significant penalties for noncompliance	Monitor adverse, beneficial, direct, indirect, cumulative, and sustainability effects
Establish follow-up performance standards	Monitor effectiveness; modify actions based on monitoring results
	Employ ongoing scoping to modify follow-up program in response to changing context and to long and short-term environmental changes

Table 4.5 (*Continued*)

Regulatory Level	Applied Level
Ensure government has legal authority to require independent audits of decision-making effectiveness and environmental outcomes Issue regularly updated, follow-up guidance materials; modify based on follow-up results	*Methodology* Ensure mitigation/compensation and follow-up are practical, cost-effective, verifiable, manageable, independent, and enforceable Clearly define and substantiate follow-up performance criteria (e.g., standards, targets, and indicators) and thresholds/criteria (e.g., when remediation needed); should be rigorous and reflect best practice Substantiate spatial study areas, temporal boundaries (frequency and duration), and monitoring areas Ensure monitoring information and outcomes are easily measured and unambiguous Identify and substantiate information sources, sampling designs, and procedures for filling gaps Identify and substantiate monitoring, evaluation, management, and communications methods Apply a precautionary approach; ensure capacity to provide early warning about irreversible trends Explain and substantiate results Subject follow-up to peer review Ensure adequate resources for follow-up
Research Sponsorship and Good Practices Sponsor follow-up research Sponsor follow-up effectiveness reviews of IA systems and of IA utility Ensure that IA is followed up Integrate substantive objectives and principles into IA requirements Emphasize the role of follow-up in determining substantive outcomes Integrate follow-up results into IA quality control and environmental databases, education, and capacity building	*Consultation and Collaboration* All parties should clearly commit to follow-up Ensure monitoring sufficiently frequent to be useful to stakeholders without burdening implementation All parties should seek to openly cooperate in follow-up without prejudice Decisions and actions resulting from follow-up should be fair, transparent and communicated directly to stakeholders Integrate community and indigenous perspectives and knowledge Inform and actively engage local communities and other interested and affected parties in follow-up (including provision for community-based follow-up) Establish and actively participate in regional monitoring groups and multistakeholder bodies Recognize limits and pitfalls of negotiated environmental agreements Provide feedback on follow-up process and outcomes Ensure effective dissemination of follow-up results
Institutional Arrangements and Auditing Establish independent oversight of follow-up Establish and refine links between IA and other forms of environmental planning and management Ensure adequate resources for follow-up and enforcement (including inspections, inspectors, education, and capacity building) Enhance environmental databases Institute quality assurance Institute tracking system for IA and follow-up document performance Institute annual compliance audits Institute public follow-up registry Provide for compliance monitoring (inspections, regulatory permits, agreements)	*External Connections and Theory Building* Link to and build on existing monitoring efforts Demonstrate compliance with pertinent regulatory requirements and public policies and objectives Demonstrate compliance with approval conditions Identify follow-up lessons and adjust as needed Integrate follow-up results into all stages of planning system Adhere to good practice standards Promote continuous learning from experience to improve future practice, including drawing upon and contributing to national and international networks Contribute to theory-building and testing Seek to demonstrate follow-up benefits

Sources: AGC (2004, 2008), Australian Government (2011d,f), Barth and Fuder (2002), Burdett (2008a), Burdge (2004), Canter (1993a), Canter and Atkinson (2011), Cashmore (2004), CEAA (2007d,e,f,g, CEAA,2009b, CEAA,2011a,b), Cherp et al. (2011), Craik (2008), Crawford et al. (2010), Devlin (2011), Eccleston (2008), EC (2002, 2010, 2011a), Emilsson et al. (2004), Evaluation Partnership (2007), Fuggle (2005a), Hanusch and Glasson (2008), Hayes and Morrison-Saunders (2007), Herring (2009), Hunsberger et al. (2005), Kemm and Parry (2004a,b), Law et al. (2005), Lee (2006), Lundberg et al. (2010), Marshall (2005), Marshall et al. (2005), Morrison-Saunders et al. (2003), Morrison-Saunders and Arts (2005), Morrison-Saunders and Sadler (2010), Nilsson et al. (2009), Noble (2009a), Noble and Birk (2011), Noble and Storey (2005), Partidário and Arts (2005), Persson and Nilsson (2007), Pölönen (2006), Ramos et al. (2004), Ridgway (2005), Sánchez and Gallardo (2005), Slotterback (2008), Smit and Spaling (1995), Swor and Canter (2011), Thérivel and Ross (2007), Thompson (2000b), Tinker et al. (2005).

4.7 SUMMING UP

In this chapter, we test the premise that IA processes, documents, and methods should be more scientifically rigorous. We present two practice-based stories where the role of science in the IA process is an issue. We provide the conceptual underpinning for a rigorous IA process. We describe a scientific IA process as it might be applied at the regulatory and applied levels. We address IA theory building at the SEA and project EIA levels. We provide examples of IA theory building for various IA types. We address the contemporary challenge of good practice follow-up.

The two stories demonstrate that there is a potential role for the sciences in the IA process. The first story illustrates how the lack of sound, contextually appropriate, social science, especially if not effectively married with community and indigenous knowledge, can undermine IA credibility and effectiveness. The second story demonstrates the importance of a cautious approach to applied science in uncertain and sensitive environments, the need to extend the consideration of biodiversity to encompass noncharismatic and noncommercial species, the potentially significant decision-making role of biodiversity, and the value of highly qualified and experienced scientific investigators.

The effort to formulate a rigorous IA process begins with an overview of the major criticisms advanced by critics. The thrust of these arguments is that IA should be treated as a form of applied research, consistent with prevailing standards and protocols of analytical science. This view is not uniformly shared. Some suggest that scientific standards are inappropriate. Others argue that the standards should be tempered.

Most commentators use analytical science as the touchstone in advancing their arguments. Consequently, analytical science is treated as the departure point. Key analytical science terms are defined. Examples of characteristics commonly ascribed to analytical science are listed. In attempting to establish a foundation for a rigorous IA process, it quickly became evident that the discussion surrounding the role of science in IA is part of a much larger, protracted, and often heated series of debates. A highly selective and simplified version of these debates is presented. Ten sets of opposing positions are presented, together with middle-ground positions. The debates concern such matters as whether science (and by extension a rigorous IA process) should strive for absolute truth, whether it should be rigorous or relevant, whether it is objective or subjective, whether it is beneficial or detrimental to the environment, and so on. IA process management implications are identified for each debate. The arguments are all potentially instructive for IA practitioners. In most cases IA process management will likely occupy a middle-ground position, but one tempered by a need to move closer to one position or the other depending on the IA activities involved and on contextual characteristics.

Regulatory scientific IA process management to this point has largely consisted of identifying general science-related principles for application in IA practice. Examples of rigor-related initiatives derived from the four jurisdictions are cited.

A detailed depiction is presented of a rigorous IA process. The IA process is treated as an experiment, consistent with analytical science. The focal point of the start-up activities is an initial set of hypotheses and an experimental design. The initial hypotheses are preliminary alternative explanations suitable for testing. The experimental design is a research program for testing the hypotheses. The latter integrates such matters as problem definition, objectives, context, need, and methods.

The baseline analysis involves selecting and applying multiple and reliable environment criteria and indicators. Preferably, the indicators can be aggregated or disaggregated. They provide a dynamic picture of trends and patterns. The analysis focuses on sensitive and significant environmental components, functions, and processes. Predictions are deduced from the hypotheses. The predictions pertain to effects from the proposed action and from options and mitigation measures. Interrelationships are addressed through conceptual and quantitative models and theories. The models and theories trace patterns of causal connections. A second round of model and theory building is usually necessary to address interconnections among models and theories. Hypotheses are tested prior to approvals using comparative, control, case, and pilot studies and after approvals using monitoring and follow-up studies. Gaps, limits, and uncertainties are explicitly identified together with implications. Interpretations, preferably supported by statistical analyses, are explicitly identified and substantiated. The scientific findings and interpretations are assumed to provide a sound decision-making basis. Postapproval activities involve both further hypothesis testing and contributions to the scientific and IA knowledge base.

The IA process extends from existing natural and social science knowledge. Ample use is made of scientific methods. Independent, skilled, and qualified scientists drive the process. The scientists strive to ensure a rigorous, open, and objective process, consistent with scientific principles and protocols. Peer reviewers assess the findings and procedures. Scientists interact and maintain contact with the broader scientific community. Stakeholders are involved prior to decisions and in reviewing documentary outputs. Documentation is consistent with good scientific practice. Research findings and methodological innovations are circulated and published, wherever practical. The process is adapted, as needed, by drawing upon alternative scientific paradigms—for example, holistic, management, complexity, and civic scientific approaches.

The relationship between science and IA is complex. The application of analytical applied science standards to SEA and project-level EIA can, depending on the context and prevailing perspectives, be tempered, reduced, reinforced, challenged, refined, or structured. The relationship also varies by IA level and type and is influenced by science types (e.g., sustainability science) and related fields of theory and practice.

Examples of IA theory-building, in general, at the SEA and project EIA level, and for substantive IA types (SA, EcIA, SIA, and HIA) are presented. Cross-cutting themes are identified. Applied theory-building characteristics for each IA type are identified.

Examples of good IA practices regarding follow-up are presented both at the regulatory and applied levels. The analysis addresses both applied and regulatory means and procedural and substantive ends and outcomes. Regulatory level good practices address measures pertaining to requirements and guidance, the sponsorship of research and good practices, and institutional arrangements and auditing. Applied level good practices concern process design, scoping, methodology, consultation and collaboration, and external connections and theory building.