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"Models" for Sustainability Emerge in an Open Systems Context

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Abstract

Participatory Integrated Assessments (PIAs) and community engagement to foster interactive discourses about sustainability have also to confront a need to understand complex and linked social-ecological systems within which sustainability is sought. Over the last 30 years or so, a number of approaches involving collaborative research have been taken under the general rubric of "complexity studies," and they have been pursued largely independently by groups of natural scientists and mathematicians, or social scientists and historians. There have been at least three overlapping approaches taken. Twelve examples of these are identified and briefly discussed. Applications of complexity studies to PIAs help justify and inform the processes used for assessments, identify key concepts and arguments that the assessments will likely have to address, and provide broad interpretive backgrounds for the larger scale and longer duration systemic processes which nevertheless can impact upon or constrain the phenomena that PIAs consider at smaller scales. A major challenge is how to make these systems perspectives accessible and usable for PIAs. Given the tasks implied by this, a special role is identified for an academic network to keep track of and help develop complex systems thinking while also interpreting it as possible inputs for PIAs.

Keywords: Models, Sustainability, Participatory Integrated Assessments

1 Introduction

Intuitively, "sustainability" is a societal ideal worth pursuing, although it does become somewhat elusive when probed more deeply. The ideal implies the existence of the appropriate knowledge and governance capacity to maintain economic vitality with social inclusiveness in opportunities and benefits, provide for ecological sustainability and the protection of biodiversity to guide the use of resources, and promote social equity within and across groups and generations. All three are necessary and no one of them alone is sufficient. These

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requirements must also hold across a range of spatial and temporal scales. The key issues rather quickly become those associated with fundamental processes to nurture rather than attributes to perpetuate, and all have to be carried out in a world of many unknowns and unknowables.

"Participatory Integrated Assessment (PIA)" and "community engagement," in some form, are required for the exploration of issues concerning "sustainability" for any one or more of three main reasons—to combine knowledge and experience from a number of sources so that the unknowns are not just conspicuous oversights; to foster social learning through a process which inevitably exposes participants' lack of knowledge while also challenging beliefs and values; and to develop sufficient mutual trust so that "trade-offs" can be reasonably discussed while still retaining the basic principles underlying sustainability. Any methods that can help with this must surely be welcomed, such as models which embody the scientific knowledge that should inform the participatory processes. Unsurprisingly, much of the PIA and related literatures become heavily focused on the models that are used for whatever is to be assessed. The models themselves have become increasingly sophisticated: for example, the global climate models of climate change (the GCMs), geographic information systems for assessing landscape attributes (the GISs), and models of sustainable regions (QUESTs).

Although created to help the general public, "decision-makers," or other groups to understand better the phenomena of interest, the models themselves can easily become the primary focus of interest or criticism. The introduction of models for group consideration can itself be sufficient to elicit questions about the purpose they have and the uses to which they may be put. Those who delve into the internal workings of the models may spot the "world-views" of the modellers that are otherwise hidden by unspecified assumptions, and contradictions between statements about uncertainties associated with various phenomena being modelled and the certainties implied by the mathematics used by modellers to incorporate them. Privileged disciplinary interpretations, tractable models, and quantitative precision are highly valued attributes in academic model-building, but what is ignored cannot always be dismissed as unimportant. Ideally, the participatory process will bring this out. But in so doing, it can make the models rather than the phenomena they try to represent become the primary foci of attention, as a growing literature about the use or misuse of models indicates.

One alternative to this is to not use models that come "pre-packaged" with all these questions embedded in them. This is not just a matter of relative convenience. The science-based models in particular can have a clockwork universe built into a number of their assumptions with all the unknowns conflated as "risk" to be further tamed with more discipline-bound research. It is a reassuring world, for academia as well as "decision-makers." But it may be highly limited in its application or just fundamentally wrong. "Complexity studies" suggest this is so. But this too, should be examined.

Viewing sustainability issues as embedded in complex open systems, especially those depicted as interdependent "social-ecological systems," implies that models appropriate for a given situation emerge from the context of place. The relevant conditions of place are some mix of systemic interactions across a range of spatial and temporal scales and external constraints from the systems' "environments." PIAs would have to consider the scope of the system dynamics in the place where the assessments are done. This is to help assure that the immediacy of the PIA interests does not inadvertently send the assessment into parochial or misleading directions.

The following section (Section 2) depicts the main attributes of complex open systems. It then summarizes 12 different approaches that different groups of scholars have used to investigate salient properties of biophysical and human social systems. The particular insights each might bring to a PIA are also noted. A concluding section (Section 7) addresses questions about how best to incorporate systems understanding into a given PIA in ways that can enrich rather than disrupt the process.

2 Complex Open Systems

The overall "gestalt" that portrays complex open systems can be viewed as a development of general (open) systems theory originally associated with L. von Bertalanffy and colleagues in the 1950s and 1960s. Attributes and processes of these systems are characterized by:

- Self-organization—morphogenesis through positive feedbacks dominate over negative feedbacks for extended periods of time;
- Emergent properties—not discernable in 'parts' alone, but are a function of the entire system;
- Driven by exergy dissipation—non-equilibrium thermodynamics & dissipative structures including development of new units of organization;
- Multiple domains of stability ["attractors"]—systems can reconfigure ('flip') sometimes rather suddenly ["bifurcations"] into other "basins of attraction";
- Hierarchical organization (systems-within-systems)—discontinuities in the distribution of structures across scales ("holons")—leading to "holonarchies" or "panarchies";
- Developmental trajectories—co-evolutionary, structured by relatively small set of processes operating across scales;
- Strongly influenced by initial conditions of place (resources, constraints)—the systems have individual histories;
- Phase cycles—including collapses and starting over (no rigid "periodicities", but rather transformations from one phase into the next);
- Inherent indeterminancies within the systems—changes associated with contingencies and propensities;

- Large realms of uncertainty in knowledge (as well as indeterminacies)—can at best develop scenarios but not predictions.

Therefore, the contexts for "sustainability" analyses using PIAs are integrated social-ecological systems having these characteristics, complete with indeterminacies, uncertainties, and complete unknowns. There is no one best way to explore or think through systems phenomena of these kinds. One can enter the inquiry from just about any academic or professional field and from other kinds of "lived experiences."

3 Approaches to Interpreting Complex Open Systems

Over the last 30 years or so, a number of different approaches have been taken through collaboration among scholars, or among some wider range of participatory groups, to explore complexity and its implications. Considering only the more academic-based endeavours, some of which have incorporated "post-modern" critiques, there have been three main lead-ins to the explorations—search for "sense-making" processes that can lead to understanding and action within complex systems settings; formulation of detailed case studies of similar kinds of systems as they change over time in order to discern underlying patterns which may have causal importance; or elaboration and refinement of conceptual frameworks viewed as a pre-requisite for posing penetrating questions about systems of interest. Each entry point soon touches on the arena of the other two.

Moreover, these approaches have been explored by groups of natural scientists and mathematicians, and by groups of social scientists and historians, but not (so far as I know) by these two main groups working extensively together. This "two-cultures" divide remains deeply embedded. Some from their natural science base make generalized claims about the human world conforming to the universals they see associated with biophysical phenomena, but never go much beyond analogies or generalities. Others from the social science base view complexity studies of scientists as evidence of a fundamental epistemological crisis within science itself, which threatens its legitimizing role for "modernism" and the underlying ideologies of liberal democracies and industrial capitalism.

Table 1 identifies three main approaches with examples from both groups. Like any taxonomy, there would be debates about the categories and distinctions among them, or among examples assigned to each. There are also individual scholars who transcend some particular "box" in which they have implictly been assigned. There are at least three ways in which these approaches can inform a PIA and community engagement process. One is to help justify a PIA and suggest ways for the engagement process to be organized. A second is to identify particular ideas or points that are emphasized in these writings and should be thought about as part of the process. The third is identification of broad interpretive contexts within which issues of sustainability have to be

Table 1: Approaches to Complex Systems Studies

	Natural Science Origin	Social Science Origin
Sense-making processes for understanding and action	Artificial worlds Post-normal science	AMESH [see text] Sociocybernetics
Comparative case studies—Patterns and comparisons	Panarchy and resilience Self-organized criticality	World-systems analyses Regulation theory
Development of conceptual frameworks	Ecosystem approach Ascendency	Human strategies in complexity Societal autopoesis

addressed. These examples are briefly summarized below. They are grouped differently from the headings in Table 1 for the reasons indicated.

4 Justification for PIAs and Community Engagement

It is not assumed here that special justifications for PIAs are needed. However, the following two approaches to complex open systems might add further support for the assessments.

4.1 Post-Normal Science

This term was coined by Jerry Ravetz and Silvio Funtowicz to refer to situations where uncertainty is high, the need for decisions is urgent, the consequences or stakes are high, but there is little usable science to rely upon. Much of the sustainability debate is in this realm. These situations require extended peer reviews to draw upon a wider range of knowledge and experience to arrive at some judgement.

In situations where "experts" are hired by government, corporations, or other organizations to argue a particular case, other experts and knowledgable citizens are needed to expose the underlying assumptions, accuracy, [in]completeness, and ethical implications of what is being asserted. To the extent that greater accountability and transparency is brought to the decision-making process in this manner, social trust in it may also be enhanced. This interpretation of complex systems helps support PIA and citizen engagement on both epistemological and ethical grounds (Funtowicz & Ravetz, 1999; Ravetz, 1999, 2002).

4.2 “Adaptive Methodology for Ecosystem Sustainability and Health (AMESH”)

The AMESH approach draws upon complex systems thinking, post-normal science, participatory action research, soft systems methodologies, and adaptive environmental assessment and management. This assures multiple perspectives and methodological pluralism for addressing sustainability in a community engagement process. Inclusion of people most affected by local problems can bring good insights into what could be done. The success reported by AMESH carried out in developing countries was associated with inclusion of people who would normally be excluded from decision making because of local ethnic, gender, or class discrimination. The AMESH approach can be seen as a variant of PIA for cross-cultural situations. (Van Leeuwen et al., 1999; Waltner-Toews et al., 2003)

5 Special Points from Complex Systems Thinking

Some, but not necessarily all, of the ideas emphasized by these approaches may yield useful insights for issues being addressed by particular PIAs.

5.1 “Artificial Worlds”

It is argued that computer simulations are a new way to do science in the information age. There is a vast range of explorations underway through networks such as the Sante Fe Institute (www.santafe.edu), the New England Complex Systems Institute (www.necsi.org), and the European Complex Systems Network of Excellence (www.complexityscience.org). They each use computer simulations to identify rules that govern “information” processing within complex adaptive systems and the resulting emergent functional or behavioural patterns that are associated with different rules. One focus for exploration is algorithmic rules (logic) which lead to “deterministic chaos” in biophysical systems. Another, for human systems, is how artificial “agents” make decisions based on rules, but they can change the rules when new information becomes available so that the emergent behaviour is continually adapting to changing circumstances. The potential of this approach is also being explored in the context of organization behaviours.

The relationship between screen patterns and the world raises epistemological issues, including that of psychological projection and reification from the one to the other. For PIAs which use simulation models, the debates about artificial (virtual) worlds should be considered as part of the reflexivity of the process. Otherwise, as a kind of “post-normal science,” the same critiques apply about their use and possible misuse (Casti, 1995; Gell-Mann, 1994; Krugman, 1996; Morris, 1999; Waldrop, 1992).

5.2 "Self-Organized Criticality"

The inherent dynamics of complex systems can result in their reaching critical states close to some thresholds of collapse where they nevertheless remain poised for long periods. Relatively small external disturbances may trigger responses ranging from slight perturbations to catastrophic change, with a power-law distribution for the magnitude of responses that occur: i.e., from many that are of small magnitude through to a few with larger magnitudes to an occasional major catastrophy. Major catastrophies do not necessarily imply unusual or special causes. The small external disturbances can trigger responses across the entire range. The "sandpile paradigm" (Bak, 1996) has been used as a heuristic. Examples often cited are earthquakes or extinction events, but the phenomena are deemed to occur in almost all self-organizing systems. The applicability of the concept to social systems and its explanatory potential for a number of phenomena, including societal collapse has been noted (Brunk, 2001, 2002).

Devezas & Modelski (2003) combined "universal Darwinism" concepts for explanations of the general evolution of human systems through social learning, innovations and adaptations, with the idea of self-organized criticality poised within nested hierarchies of co-evolving social organizations. Disruptions from innovations or other sources cascade in power law fashion through the hierarchies. Most have little impact. Occasionally, however, some lead to quite drastic changes in economic, political and other social structures and in underlying cultural belief systems. Devezas & Modelski (2003) see prospects for elaborating "a deep theory of social order" from this perspective, one which might explain the evolution of the entire world system over the past 5,000 years, complete with the various phase cycles which unfold over periods ranging from decades to millenia.

PIAs should be aware of self-organized criticality phenomena among the issues they are considering. They are not usually predictable, but do point to questions about contingency planning for major events should they occur (Buchanan, 2001; Hodgson, 2002; Modelski, 2004).

5.3 "Sociocybernetics" (Second Order Cybernetics)

First order cybernetics refers to the cognitive interactions of observers who are observing systems outside of themselves, and through the interaction of observer with the observed, develop their perceptions and understandings accordingly. Second order, or sociocybernetics refers to the same processes but for situations in which the observers are inside the systems they are observing, and realize this. Thus their interactions with the systems could modify the systems themselves. Awareness of this is necessary to enhance reflective thinking ("reflexivity") about the "social constructivism" of knowledge that is inherent in "observing observed systems." Consciousness of this can result in "double-looped learning" if management of the system is the object of the exercise, i.e., both the goals or purpose of management as well as the means to achieve them are open to critique and change. In other situations, this "deep reflexivity" can lead to some transformation of consciousness in the observers.

There can be a regress involved in trying to understand the phenomena of observers observing themselves and others observing the system they all are in. A "radical social constructivism" for interpreting knowledge can result, to the point of rejecting even the possibility of an ontology for the systems of interest. These will be among issues that a process based on reflexivity would have to address.

Given the phenomena of "observing systems" along with the social construction of knowledge and the need for reflexivity, Midgley (2003) argues that the best approach for dealing with complexity is to adopt methodologies for interventions that make "sustainable improvements" in social conditions. Value judgements need to become explicit for setting boundaries to whatever is being addressed, and adopting theoretical and methodological pluralism to guide decisions and actions for making the improvements.

PIA processes could easily evolve into regress sequences, especially if some participants are steeped in "post-modern" critiques. Midgely's rationale seems both appropriate and supportive of PIA processes and community engagement. (Connell, 2003; Geyer & van der Zouwen, 1991; Manuel-Navarrete et al., 2002; Steir, 1992)

5.4 "Societal Autopoesis"

This approach to understanding human systems is closely associated with the German social theorist Niklas Luhmann. His theory draws upon sociocybernetics as well as the biological concept of "autopoesis" for living systems. Organisms have a fixed genetic code governing the growth and reproduction of their molecular and cellular components but at the same time they must remain "structurally coupled" with their environment to acquire essential nutrients and other pre-requisites for living. "Autopoesis" thus refers to some entity which continually reproduces itself while remaining organizationally closed but structurally open for limited contact with an outside world.

This construct has been adopted by Luhmann to define "society" as nothing more than closed self-referential communication networks which are structurally open to their environments, which in this case are other communication networks. Each such network is self-reproducing and can grow with access to resources. It filters information from its environment through strict binary codes to convey meaning for itself on its own terms. From this perspective, society is only an aggregation of such networks (vs some emergent larger entity). A somewhat modified version by Dempster (2001) interprets social organization as "sympoetic" which suggests that organizational closure is not complete but remains somewhat "ajar" and this in turn allows for some cultural evolution.

The relevance of the large literature on Luhmann's work for PIA and community engagement is rather moot. It might provide a novel explanation for the complete non-responsiveness of many organizations to changes being urged on them from sources outside of their own self-referential worlds. Dunsire (1996) has explored some implications of Luhmann's theory for governance (Bechmann & Stehr, 2002; Viskovatoff, 1999).

5.5 "Human Strategies in Complexity"

This approach to complex systems uses notions of "structuration by dialectical processes" to interpret emergent properties in social systems. This notion draws upon the "structuration theory" of Anthony Giddens which interprets social structures as emergent phenomena which are constantly created and recreated by people following rule systems to guide their behaviours. In this view, structures are not some kind of pre-existing social architecture that exist independently of peoples' lives. If rules change, so will the structures created by new rules. This notion is coupled with that of "dialectics" in which the merger of opposites (however defined) into a synthesis will in turn result in the synthesis having its own opposite to merge into another synthesis (and so on). This kind of progression can be viewed either as an ontological description of social change or as a mode of reasoning about change (epistemology), or possibly both.

The focus on emergent social structures and change as a question of rule systems, and on the formulation of opposites to whatever it is thought desirable to change, might provide worthwhile insights for strategies developed by PIAs and community engagement (Fuchs et al., 2001; Fuchs, 2001, 2003).

6 Broad Interpretive Contexts for PIA and Community Engagement

The phenomena addressed by the following approaches provide broader contextual components for many situations that PIAs address.

6.1 "Panarchy and Resilience"

These terms are associated with extensive studies by C.S. Holling and his associates. They are based on quite detailed case studies of regional-scale ecosystems and changes associated with them over several decades (e.g., New Brunswick forests, the Florida Everglades). The ecosystems exhibit four phase cycles over a number of years or decades during which long-term relatively slow growth and development of biomass accumulation is interspersed with shorter periods of "destruction" and renewal events which are triggered by external events (e.g., forest fires). These phase cycles operate at different scales set within loose hierarchical structures ("panarchies") such that cycles at one scale can sometimes cause change at other scales. "Resilience" is related to the relative speed and extent of recovery during the destruction and renewal phases.

This interpretation of ecosystem dynamics forms the basis for extended critiques of resource management practices which focus on resource extraction rather than on maintaining the resilience of the ecosystems growing the resources. The paradox (or "pathology") of resource management arises from contradictions between management actions which "produce" the resources and encourage local economic dependency on their continued provision, and the fact that the management actions also stress ecosystems to a point where, in extreme circumstances, some unanticipated event triggers their sudden collapse, along with the dependent local economy. An "adaptive management" strategy is advocated for these largely unknown situations. This strategy treats management as a kind of on-going experiment that should be monitored widely, especially in terms of changing ecosystem conditions, in order to give the signals for changing management approaches before they drive systems to collapse. The "panarchists" believe that the same situation applies to human systems which can be analyzed the same way either independently or as integrated social-ecosystems.

For PIAs that recognize ecological and/or resource systems as major components of what they are striving to assess, diagnoses based on panarchy and resilience should be included. (Carpenter & Gunderson, 2001; Gunderson et al., 1995; Gunderson & Holling, 2002; Holling, 1996, 2001; Peterson, 2000; Walker et al., 2002; Elmqvist et al., 2003)

6.2 "The Ecosystem Approach"

This approach to complex systems shares the phase cycles interpretation of panarchy and resilience as well as the assumptions that the analyses also apply to human systems. It differs primarily in the emphasis that the ecosystem approach gives to the fundamental importance of non-equilibrium thermodynamics. The high quality solar energy ("exergy") is the driver of ecosystem development and is the essential pre-requisite for processing of materials and "information" (defined as the genetic code of organisms and biodiversity of ecosystems) into elaborate food webs; at the same time this helps dissipate the exergy. Exergy also drives ecosystems along some development path subject to constraints from initial conditions of place, and provides a crucial pre-requisite for the maintenance of their "integrity." If pushed beyond some thresholds, ecosystems can also reconfigure quite suddenly, in order to continue with their dissipation of exergy.

This interpretation of ecosystems addresses the generative side of evolution, i.e., the underlying processes which generate such rich biotic variety that natural selection processes can then occur. Through detailed studies of the energetics of foodwebs, and of their seasonal variation in Chesapeake Bay, Ulanowicz (1997) described the development of ecosystems in terms of their "ascendency" whereby at some point an internal balance is maintained between the continued development of dissipative structures (more elaborate foodwebs) and the conservation of adaptability ("ecosystem overhead") as a reserve for future adaptations to changing environmental conditions.

The non-equilibrium energy underpinnings of systems is deemed to be applicable to human systems as well. These too are dependent upon exergy as well as embodied energy in fossil fuels. The proliferation and complexification of human organizations in response to problem-solving needs or opportunities can be viewed as elaborations of dissipative structures that are crucially dependent on energy resources. Kauffman (2000) suggested that the proliferation of dissipative structures in response to exergy in physical systems, ecosystems, and human systems, can be viewed as another law of thermodynamics, one that applies for open systems in contrast to the second law of thermodynamics about entropy which applies in closed systems.

Allen et al. (2003) elaborate on the thermodyamics of ecosystems while emphasizing the crucial importance of energy for the sustainability of human systems. They use as examples, historical and archaeological studies of collapsed societies that were unable to maintain their energy and other resource bases. They also advocate "supply-side" ecosystem management which focuses on the restoration and maintenance of entire ecosystems in place of devoting attention only to the extraction of resources from them, a prevailing practice in resource management.

While the ecosystem approach as sketched above is more theoretical than applied, it points to issues about the importance of energetics and of the sustainability of the proliferation of organizations. PIAs with a more restricted focus might be tempted to ignore energetics or encourage proliferation of organizations as solutions (Allen & Hoekstra, 1992; Kay et al., 1999; Tainter, 1988, 2000; Tainter et al., 2003).

6.3 "World-Systems Analyses"

This approach to complex systems is probably the most heroic of them all. At its grandest extent it sketches the "rise and demise" of entire societies from pre-neolithic times some 12,000 years ago to the present era (Chase-Dunn & Hall, 1997) or globally over the past five millenia (Frank & Gill, 1996). More attention has been given to the past 500 years or so, the period which has seen the rise (and more recent curiosity about the demise) of global capitalism in a world of nation-states (Wallerstein, 1999).

From the world-systems perspective, the material base for societal change comes primarily from the "unceasing accumulation of wealth" which is the driving force of capitalism and the purpose of existence for corporations, combined with struggles for domination over the state apparatus for control over territory, resources and people within nation-states. Rivalries and conflicts abound, but the wealthy need the powerful to protect their wealth and the conditions under which they can continue to accumulate it, and the powerful need the wealthy in order to maintain their territorial control. As this has unfolded repeatedly over many decades it has created a functional and spatial differentiation of the world society into core countries having the most advanced technologies and organizational know-how for different economic sectors, peripheral countries which supply little more than resources and cheap labour, and the semi-peripherals in between which usually have an urban sector more closely linked to core economies and rural areas that are peripheral. The same structural relationships are replicated within countries as well.

Phase cycles or transitions of particular interest in the world-systems perspective are all multi-decadal. They include economic phases of expansion, diffusion and contraction over periods in the order of 50–60 years. The phenomena are usually referred to as "Kondratieff, or K-cycles" which are associated with access by core countries to major new resources and/or technological innovations which can undermine and replace economies based on older technologies. Over much longer periods, the "systemic cycles of wealth accumulation" in the core economies shift their geographic location when overseas investments and/or growing financial speculation provided by institutions in the old core region generate better rates of return elsewhere. The eventual result is that a new regional economy develops from such investments while the old region coasts along with slowly aging infrastructures and unresponsive institutions (combined often with assumptions about cultural superiority). Over a century or more, the new regional centres for wealth accumulation regularly outcompete the old, and the inter-regional disputes become increasingly politicized.

There are also phase cycles associated with the political rise and demise of hegemonic powers that preside over the world order. Economic and political conflicts that develop between a prevailing hegemon and its allies from a challenger group lead eventually to drawn out international wars. When a challenger succeeds by "winning" the wars or just surviving them in better economic condition than other combatants, it then can set or enforce the international groundrules to direct some new world order for security and trade in which the winners are the primary beneficiaries. For a time this is widely accepted in the aftermath of major wars. Some decades later, this world order becomes increasingly less relevant for dealing with new problems and challenges to it. The hegemonic arrangements then begin to lose their legitimacy and new coalitions form to challenge the hegemon or some other contenders on the world scene. The four phases of a hegemonic cycle, given the history of several of these over the last several centuries, also take a century or more to unfold. In each case, the defining wars (e.g., Napoleonic wars; World Wars I&II) were the most destructive ever known up to that time.

Besides these grand cyclic phases, the world-system has exhibited major trends or "trajectories" of development. These include extensive population growth along with growing inequalities; an increase in the number of nation-states; a large increase in the number of transnational corporations and international "civic society" non-governmental organizations; a massive increase in economic production combined with increasing capital intensity of production (labour displacement); intrusion of commodified goods and services into all spheres of modern life; and massive environmental degradation in many forms. There is some question about whether or not the major phase cycles of old can still play themselves out under conditions of approaching global ecological or other limits. If not, then some entirely new "system flip" may be in the offing.

These grandiose perspectives provide for a "snapshot-in-time" of the historical forces which are unfolding and set the background for any more localized dialogues about sustainability. At the present time then, in the world polity, the US as the most recent hegemon has been in slow decline for the past 30 years or so to the point that it now relies on brute military force to rule in place of exercising a trusted leadership with broad-based legitimacy and acceptance.

Delegitimation processes are well underway for most of the post-world war international organizations such as the UN system or NATO. The major centres for systemic cycles of wealth accumulation are shifting from the US (and Europe) to Asia which is fast becoming a significant economic competitor in the global economy. The past 30 years or so coincided with a "downswing" in the K-cycle, but arguably a new upswing is underway which is driven by information technologies, nano-technologies, robotics, and biotechnologies, many of which are thriving in Asia as much as they are in the US and Europe.

Any PIA is set within a global context with these kinds of issues. Interpretations of them could vary widely, especially since the world-systems perspectives are not supportive of prevailing ideological justifications for economic or military responses to "globalization." But these phenomena are not merely passive backdrops for the real world of local and immediate concerns. Systemic interconnections point to constraints, perhaps serious ones, on what can be achieved or maintained locally by PIA and community engagement exercises (Arrighi, 1995; Arrighi & Silver, 1999; Bornschier & Chase-Dunn, 1999; Boswell, 1995; Boswell & Chase-Dunn, 2000; Chase-Dunn & Grimes, 1995; Hopkins & Wallerstein, 1998; Modelski, 1987, 1996; Wallerstein, 1991, 1998, 2003).

6.4 "Regulation Theory"

This approach to complex systems is best seen as a sub-system of world-systems although it has been apparently developed quite independently of it. The "theory" is an interpretation of events that have unfolded in a number of the core-country economies over the last 30 years or so during the "downswing" of a K-cycle. The underlying theme is the embedding and disembedding of capitalism in other dimensions of society that provide essential support for capitalism while also being exploited by capitalism unless it can be reigned in. The narrative of regulation theory begins with what was once (c1950s-1960s) the ideal of independent nation-states, each having a largely self-contained and balanced economic structure supported by strong social policies. They engaged in trade with other national economies through state-mediated rules about exchange rates, tariffs, limits on foreign ownership, and other measures all intended to protect the integrity of national economies and polities. This ideal has been called a "Keynesian welfare national state with a Fordist mode of economic organization" (Jessop, 2002).

This ideal became increasingly unworkable, especially with the concurrent K-cycle downswing in the global economy, and it led to the corporate capitalist neo-liberal backlash to remove or undermine the policies and regulations that nation-states had in place. The "freeing" of the private sector from state controls led to the expansion of global capitalism and the strengthened influence of trans-national corporations. State powers were redistributed "upwards" to international institutions that fostered global capitalism, "downward" to more local levels of government under the rubric of subsidiarity or debt reduction, or just abandoned as no longer necessary ("de-regulation"). The resulting "Schumpetarian workfare postnational regime" was accompanied by the "structural coupling and co-evolution of accumulation regimes and political regimes" (Jessop, 2002, p. 3 & 125). As the social and environmental costs and contradictions of this neoliberal alternative become increasingly apparent, so will attempts to find ways to re-embed capitalism into society to help capture some economic benefits and curb its destructive tendencies.

Issues of "governance" also arise in this context. They are often posed as a need to broaden the basis for "governance" to include "civic society" organizations working in partnerships with government and corporations. Issues of deliberative democracy and legitimacy of "governance" arrangements also emerge.

The PIAs in search of sustainability at local and regional scales may well be manifestations of this situation, including a perceived need for readjustments or more fundamental change. (Amin, 1997; Bridge & Jonas, 2002; Dryzek, 2001; Jessop, 1997, 2000, 2001)

7 Building Complex Systems Thinking into PIAs and Community Engagement

None of these approaches to complex systems thinking can just be "off-loaded" to individual PIA exercises in a casual way, as yet one more set of imponderables for participants to absorb. There would have to be some selectivity depending upon the purpose of a PIA and the contexts that gave rise to issues it addresses. Given the tasks this implies, a special role for an academic network opens up, one which could link into key sources (often other networks) of people who are generating the approaches such as those noted above. Tasks would include participating in these endeavours or just keeping track of intellectual developments in them, interpreting their main arguments succinctly and reliably for possible use in PIAs and other community engagements, and devising means for introducing and explaining them as inputs for the processes themselves. Connections might also be sought with "dynamically evolving large scale information systems" having search engines that will gather relevant information from clusters of related content continuously and also refine search capabilities through interactions with users of this information (Casti & Dum, 2002). There is also work to be done on analyzing the implied ontologies and epistemologies of particular concepts (e.g., "information") or other vocabulary used in such widely different contexts as those identified in Table 1.

All of this is best thought about as background preparation that should be part of the planning for a PIA. It would go along with considerations of the issues to be posed, or would likely arise from open discussions, and the kinds of participants who are invited for a PIA, or are expected too show up if meetings are open. The preparation should include the facilitators who have to be open to new substantive ideas themselves. Members of an academic network would review the range of intellectual contributions that can be drawn from complex systems thinking, identify some key ones that pertain quite directly to the situations to be explored by a PIA, and clarify questions facilitators might have about them.

Otherwise, it would be a judgement of facilitators about when and how best to introduce these insights during the PIA process. Backup reference items or information displays might be considered to help do this constructively. Predesigned models are not ruled out, but neither should they rule over what needs to be discussed.

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