Chapter 1

MAPPING SUSTAINABILITY

Logic and Framework

Nazli Choucri

Introduction

While almost everyone agrees that the quest for sustainable development is one of the most significant challenges for all societies in all parts of the world, there are considerable disagreements about the specific meaning of *sustainable development* and a range of contentions surrounding the term *sustainability*. This situation is particularly problematic in light of the explosion of information about sustainability now available in electronic form, the increasing use of the Internet as a mode of communication and exchange, and the difficulties often encountered in locating and selecting relevant knowledge on any specific set of issues. These conditions create a critical imperative, namely, one of devising a strategy for organizing and managing information flows about sustainability on the Internet, where quantity dominates and quality is often sacrificed. This imperative revolves around matters of *content* and of *conduit.*

The purpose of this chapter is to present a conceptual framework to guide our understanding of the overall issues at hand and examine their constituent elements in order to organize existing knowledge on sustainable development. The conceptual framework also serves as the basic architecture for thinking about, searching for, and retrieving knowledge bearing on the specific aspects of sustainability of interest in any situation. Since the process of engaging in transitions to sustainability is itself a moving target, we would expect that efforts to develop a knowledge-base on sustainability will yield results that change over time. In this context, the challenge is to capture the elements that appear to be most relevant, and to discard others as appropriate.

A fundamental prerequisite, however, is to recognize the all-encompassing context within which such issues take on their most fundamental

N. Choucri et al. (eds.), Mapping Sustainability: Knowledge e-Networking and the Value Chain, 3–28.

meaning, namely the nature of the global system and globalization process. It is no longer possible to consider sustainability of individual entities, states, or groups without taking into account the broader configuration of natural and social systems within which all entities are embedded. Accordingly, in this chapter we highlight some of the most important facets of the global system as currently understood, particularly focusing on critical features of the globalization process. These facets frame the terms of reference, within which we will engage in Mapping Sustainability.

1.1 Globalization and the Global System

Over the course of many centuries, a major alteration of the international system has occurred as populations expanded their activities and political entities broadened their reach. The concept of the global system – recent addition to the semantics of international relations and world politics – formalized our recognition of the powerful interconnections among natural systems and social systems. This concept highlights the embeddedness of social activities within prevailing environmental contexts and all attendant considerations. An inevitable extension of this understanding is reflected in the notion of globalization. The ongoing globalization – a legacy of the 20th century – may well constitute the greatest challenge to world populations since the end of Western European Feudalism, which led to the Congress of Westphalia and the establishment of the nation-state system.[1]

In principle, the global system refers not just to the social, political, and economic systems, but also to the earth, its geological and geographical features, its flora and fauna, and its surroundings (including the sun) which provide a unique and indispensable environment for life as we experience it. In a sense, the natural environment holds us all hostage and the implications of such bindings have become increasingly more complicated as population growth and advances in technology have enabled human beings to extend their activities and interests into remote enclaves of the planet (and space). As a result, we increasingly intervene in natural processes, often blindly and without knowledge of the consequences.

Such interventions lead to toxins. Once we have released our toxins into the soil, water, and air, for example, nature's processes take control. Once released, the trajectory, intensity, and damages of effluents are seldom, if ever, subject to legal or strategic control. The global system remains disrespectful of, even oblivious to, our political regimes and state boundaries.

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[1] The Westphalia principles defined the state and its sanctity as the basic unit of international relations, and thus reinforce those very factors that undermine the emergence of a global, rather than an international, system.

And the forging of cyberspace, an essentially technological achievement, invariably alters the traditional distributions of voices in international relations, shaping new domains of interactions relevant to human behavior, the role of the state, and the structure of the international system.

In this connection, Peter Haas argues that the growing importance of epistemic communities is shaping our understanding of the global system and its fundamental processes, and that this role is a clear acknowledgement of the interconnections between natural and social processes (1989).[2] Haas argues that these environmental conditions constitute a formal recognition of a *fourth image reversed* scenario, where international politics are shaped by global conditions.[3] It can be compared only indirectly to Peter Gourevitch's *second image reversed* since the latter focuses entirely on social interactions (political, economic, strategic, etc.) with no recognition of the natural system (Gourevitch, 1978). With these considerations in mind, later in this chapter we shall point to key features of the changing contexts for states and firms, and then focus specifically on our strategy for charting this new 21st century reality.

More immediately, we can consider the forging of cyberspace and the new domain for the conduct of political discourse to be a critical feature of the global system. Clearly created by human beings and their technological ingenuity, this fourth level encompasses the third image, namely the international system that is composed of state actors and others enfranchised by the state, as well as those that are commonly thought of as transnational. New policy arenas for discourse are responses to new modalities of actions and interactions are in the offing. As a result, there are new demands for global accord and coordinated action.

Whatever we may do that drastically interferes with the natural system – at any level – can have global repercussions. And any such repercussions at the global level could have local implications. Only a global view will demonstrate the extent to which war, peace, environmental, and other problems

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[2] This characterization refers to the concept of 'image' in the study of international relations which signals levels of analysis. The traditional levels – defined by the individual, the state, and the international system – were first defined by Waltz (1959) extending the notion of 'image' introduced earlier by Boulding (1956). North (1990) and Choucri and North (1993) first articulated the concept of the global system, as the fourth image. Choucri (1993) made the first extension of the fourth image, as the global system by taking into account cyberspace, as a human-created, technological driven generation of new space of interactions that transcend the conventional three images of the international system.

[3] Among the related efforts in international relations theory contributing to the articulation of the fourth image are Modelski (1996), Alker and Haas (1993), Ostrom (1990), Starr (1997), Vitousek et al. (1997), Holling (1995), and, of course, Hardin (1968) in the context of framing sustainability. Implications of the fourth image for the properties of the second image can be derived from Litfin (1998) while at the same time taking into account select imperatives of the third image. See also Pollins and Schweller (1999) "linking the levels" focusing on shifts in U.S. foreign policy over long spans of time.

impinge on one another. In this context, we need to consider how individual humans and their needs, wants, desires, demands, capabilities, and actions create, constitute, train, shape, and constrain the state and the international system, and how all three – individuals, the state, and the international system – are embedded in an overall global system.

A rather simple way of looking at global trends and select constitutive elements is presented in Figure 1.1, which shows the distribution of states in terms of carbon emission and GDP.

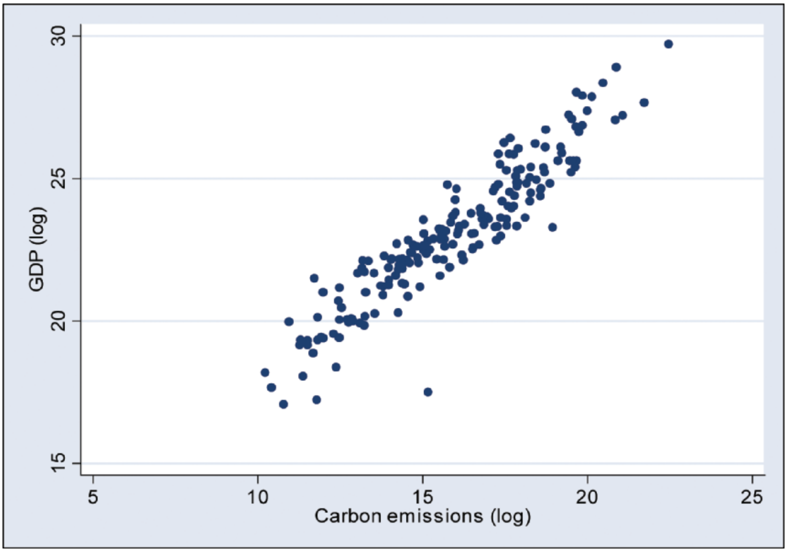

Figure 1.1 **Carbon emissions (thousands of metric tons) and GDP (constant USD), 2000. Based on observations from the *United Nations Common Database.*** [4]

An obvious inference is that poor countries produce less and pollute less; while the richer countries produce more and pollute more. What happens, however, when the poor become richer? What are the stresses that result from growth? Can sustainability substitute for growth?

In this figure, as well as all of the ones that follow, the observations displayed contain two sets of information: one pertains to the distribution of countries at one point in time, and the other pertains to the imputed evolutionary pattern of development over time. In the context of Figure 1.1, therefore, over time countries located on the lower bottom left side of the graph will gradually 'travel' along a trajectory of change that leads from lesser to greater levels of development toward the top right side.

When observed empirically, such trajectories go a long way toward helping us understand the patterns of growth, development, and evolution of

[4] All figures in this chapter are constructed using Stata 9.

states and empires from their pristine beginnings through their rises, declines, and eventual disintegrations. A different set of issues is raised in Figure 1.2, which shows the distribution of states in terms of energy consumption and population size. Since both variables represent aggregate characteristics of states, it is not surprising to observe that countries with larger population consume a greater amount of energy.

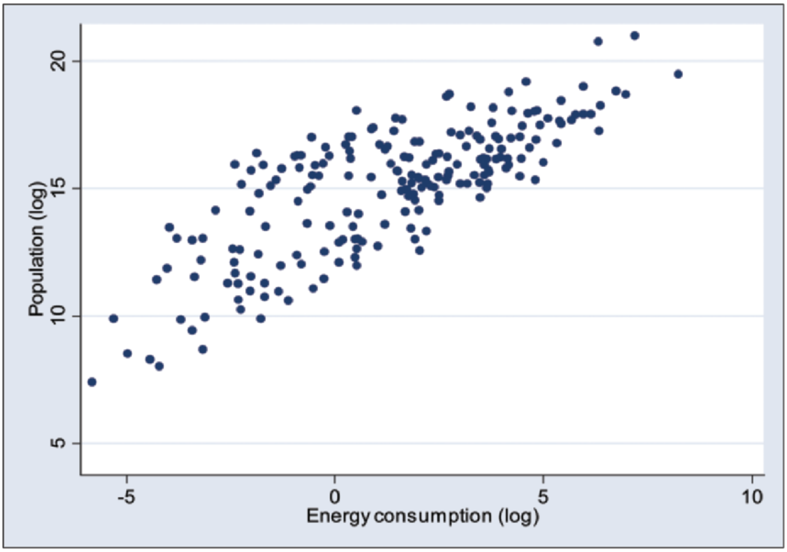

Figure 1.2 **Population and energy consumption (electricity, in millions of kWh), 2000. Based on observations from the *United Nations Common Database*.**

In still a different vein, we show in Figure 1.3 another perspective on the distribution of countries in the global system, namely the distribution of life expectancy at birth, on the one hand, and GDP per capita on the other. The obvious is worth noting since it reflects the stark reality of inequality in the international system: with few exceptions, the countries with higher GDP per capita are also those with higher life expectancy.

Finally, we show in Figure 1.4 the distribution of countries in terms of military expenditures and economic output, GDP.

Once more, we see the generic inter-state pattern signaling a now-familiar view of distribution of states worldwide. This distribution is especially informative as it allows for a simple inference. With the exception of one or two cases, it is clear that with greater material output (an indicator of wealth) come greater expenditures on the military (an indicator of security or insecurity as the case may be). Both of these factors are usually correlates of the globalization process.

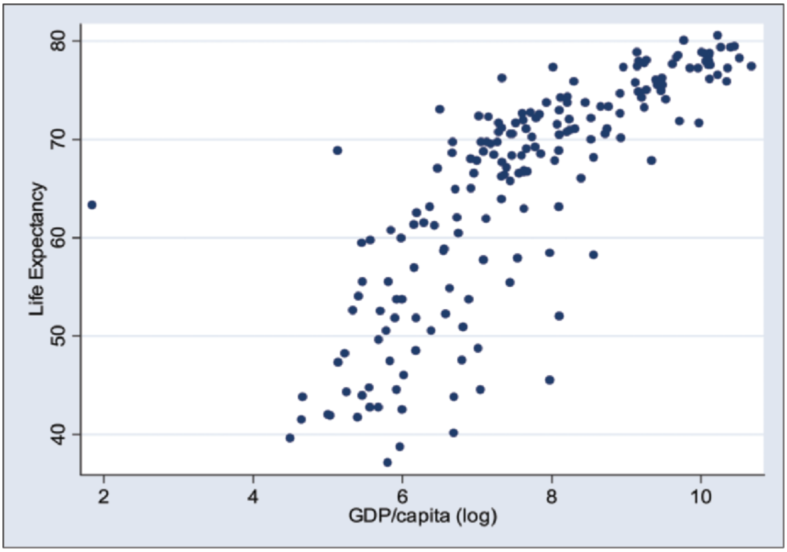

Figure 1.3 **Life expectancy (years) and GDP/capita (constant USD/person), 2000. Based on observations from the *United Nations Common Database.***

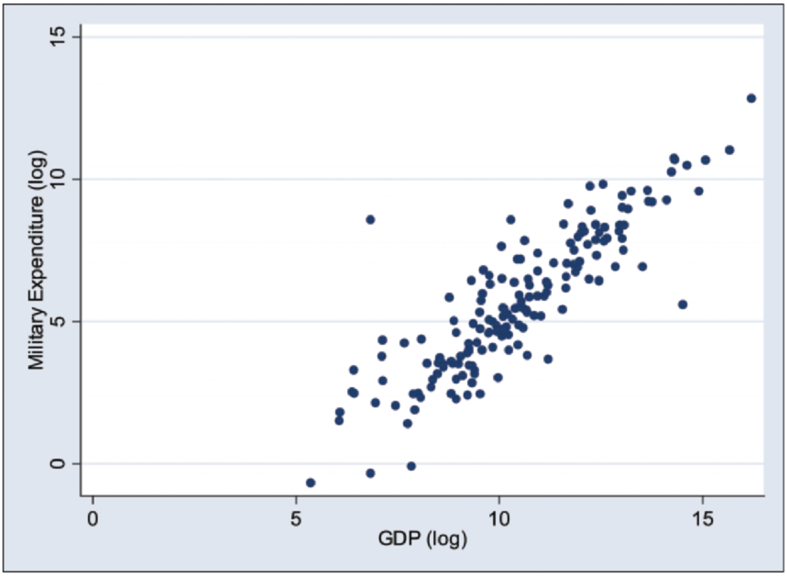

Figure 1.4 **Military expenditure (constant USD) and GDP (constant USD), 2000. Based on observations from the *United Nations Common Database.***

1.1.1 The Meanings of Globalization

Despite the dominance of *globalization* in both development and international relations debates and discourses, fundamental differences persist about the meaning of this term. It is not always easy to determine which is growing faster: the globalization debates or the globalization process itself.[5] At the very minimum, globalization refers to growing patterns of cross-border activities involving aggregations of human activities at various levels of analysis. These aggregations shape social interactions, as well as environmental considerations.

From a theoretical perspective, however, the spectrum of globalization is bracketed by two views. At one end is the conventional view, which is focused largely on economics and economic transactions; at the other end is an emergent view which stresses the dynamics and complexities of globalization.

More specifically, the conventional view defines globalization as the increased integration of national economies in terms of input, factor, and final product markets. This view focuses on *intra-state* impacts and on issues surrounding convergence and divergence of cross-border of policy responses. While the economy-centric view is important, it is very restrictive as it obscures many of the more pervasive system-transforming features of today's realities. It may also impede an appreciation of ways in which globalization creates new demands for governance induced by social, political, and economic transformations. When placed in the context of current realities, the conventional view of globalization represents the processes of growth from the perspective of those on the 'top' of the global system and pays considerably less attention to than by those situated at the 'bottom.'

1.1.2 Emergent Logics

At the other end of the continuum is the emergent logic of globalization – the view assumed in this book – which stresses the complexities and attendant interdependences created by the movements of goods, services, people, ideas, and influences across national borders. This perspective is particularly dynamic in that it is focused on *transformations* within and across states due to various patterns of mobility, notably those which strain prevailing modes of governance and forge new policy spaces as well as demands for new forms of coordinated policy responses.

In this context, we define *globalization* as the complex process engendered by (a) the movement of populations, goods and services, influences,

[5] See Castells (1996) for a sociological perspective on globalization and its challenges.

effluents, and ideas across state boundaries, such that (b) these alter the structure of national economies and societies, and create new forms of interdependencies across economies; (c) these changes, in turn, alter the subsequent movements of goods, services, people, and ideas across boundaries; as a result, (d) changes in international structures and process forge new policy spaces and (e) create demands new forms for coordinated policy responses.

In short, this emergent view centers on impacts of flows and movements along a causal chain and draws attention to the feedback logic. The causal logic flows from differential national and international conditions to shaping the movements across boundaries; from movements across boundaries to impacts on national economic, political and social structures to conditions that create new movements and new processes; from new process effects to alterations in the structure of the international system; and from such alterations to shaping of new policy spaces that, by necessity, create demands for new policy responses.

The essence of globalization lies in the transformations of structures and processes that lead to the formation of common policy spaces and require new institutional responses. This emerging logic suggests that almost everyone is involved in the process and everyone is affected – albeit in different ways. The specific manifestations of structure and process may differ, but the inherent logics and the feedback dynamics are generic in nature.[6]

Increasingly, the socio-political and economic dimensions of today's globalization appear to be knowledge-driven, making knowledge intensity one of the most significant features of the world economy at this time. While enhanced economic dependence on knowledge has fueled competitiveness worldwide, its impacts are considerably less evident in development contexts. Against such imperatives, we now turn to the deployment of knowledge for facilitating transitions toward sustainable development.[7]

1.2 Knowledge for Sustainable Development

According to *Webster's New Collegiate Dictionary*, *to know* is to "hold something in one's mind as true or as being what it purport to be"…[this] "implies a sound logical or factual basis" [and it also means] "to be convinced of…."

[6] As an example, if we consider extended enterprises, private and public, whose performance is contingent on efficiencies of the internationally distributed supply chain, the exposure to globalization pressures is not only unprecedented in scale and scope, but also rapidly changing.

[7] Such imperatives further compel us to question the wisdom of the conventional economic model that views more growth as a necessary imperative, and the requisites of efficiency as a dominant value.

By extension, knowledge refers to the "fact or condition of knowing something with familiarity gained through experience or association; acquaintance with our understanding of a science, art, technique, condition, context, etc." [including] ... the range of one's information and understanding to the best of abilities in place [as well as]… "The fact or condition of being aware of something…" accordingly, what is 'known' is that which is 'generally recognized….' However lacking in elegance these observations might seem, they aptly characterize common views of knowledge (1976).

1.2.1 Knowledge System Defined

We extend the standard view to take into account a cluster of understandings that we refer to as a knowledge system. Thus, we define a *knowledge system* as:

> An organized structure and dynamic process of interaction generating and representing content, components, classes, or types of knowledge, that are (a) characterized by domain-relevant features as defined by the user community, (b) reinforced by a set of logical relationships that connect the content of knowledge to its value, (c) enhanced by a set of iterative processes that enable the evolution, revision, adaptation, and advances, and (d) subject to criteria of relevance, reliability, and quality.

Among the most fundamental attributes of knowledge is that its acquisition and utilization follows the law of *increasing returns.* This means that the more knowledge which is obtained and used, the greater the likelihood that it will be valuable to the user. This critical feature is a distinctive input into social and economic activities. Our purpose here is only to highlight a feature upon which much of the trends toward knowledge intensity are based. The presumption is that a knowledge system has value, in one form or another, and that capturing this value is essential for enhancing knowledge intensity in economic activities. Further along, we specify the constituent elements of a knowledge market in modular terms.

Conventionally, *value* is defined as "fair return or equivalent in goods, services, or money for something exchanged" (Webster, 1976). *Value* also connotes worth of some kind, as well as being of some importance. But the terms of *value* are not implied in the core concepts, nor are its units of measurement. The value of knowledge has different meanings in private and in public settings. In public settings it is viewed in terms of facilitating the provision of services for meeting social needs and for implementing policies to improve social and public well being. In private contexts, it is often connected to economic gain, notably to market prices and conditions.

At the same time, however, harnessing knowledge is only part of the challenge. Equally, if not more, important is the ability to communicate, share, manage, expand, revise, and generate new knowledge.

As noted in the Preface*, Webster's Collegiate Dictionary* states that *to map* is "to represent … to delineate … to assign to every element of a … set an element of the same or another set," and "to be located near the corresponding structural [element]" (1976). In such terms, *Mapping Sustainability* presents a way of representing knowledge content in the domain of sustainable development, with the full expectation that such knowledge changes over time, and that its representations must adjust accordingly. For mapping purposes, the focus here is on the content-architecture – the levels, linkages and complexities – that characterizes the domain of sustainability.

1.2.2 Sustainable Development

Our view of sustainable development focuses on human activities, and places the individual, in social settings, at its core, while taking into account and respecting the imperatives of nature and natural systems. We define sustainable development as *the process of meeting the needs of current and future generations without undermining the resilience of the life-supporting properties of nature and the integrity and security of social systems.*

Extending this definition further, we differentiate among critical fundamental processes that represent the sustainability arena. These processes refer to the nature of *ecological* systems, the type of *economic* activities, modes of *governance*, and *institutional* performance. To become sustainable, a social system must exhibit a certain degree of viability within and across each of these processes. Accordingly, it is useful to consider the various features of these processes and the ways in which these processes may lead toward sustainability.

Specifically, a system will tend toward sustainability if the (a) ecological systems exhibit balance and resilience; (b) economic production and consumption account for efficiency and equity; (c) governance involves participation and responsiveness; and (d) institutions demonstrate adaptation and feedback. In short, if – and only if – prevailing trends point toward these conditions will a social system tend toward sustainability.

In this connection, access to, and effective use of, knowledge is critical in shaping and managing social goals. This knowledge imperative is especially relevant for trajectories toward sustainable development – in all contexts and in both industrial and industrializing countries. Despite advances in information and communication technologies, major political, strategic, economic and institutional barriers continue to impede the use of knowledge for policy purposes. In the sustainability domain, as in many others, the making of decisions and the formation of policy seldom draw on the full range of relevant knowledge, or utilize critical knowledge materials that may be available. Moreover, the complexity of sustainability, coupled with ambiguities in its meanings and understandings, further reinforce the difficulties of bringing existing knowledge into policy debates.

The challenge at hand does not arise from a lack of knowledge, data, information, published materials, raw observations, and so on, but rather from the absence of intellectual coherence and some internally consistent logic, which if put in place, would lead to best uses of existing materials. The dearth of integrative approaches (or frameworks) may well be among the most significant barriers preventing effective access to large bodies of knowledge that bear upon the domain of sustainable development. Different stakeholders in different parts of the world have different views and priorities about what is real, what is important, and what can be done as a result. This is especially true in the domain of sustainable development where a wide range of knowledge and knowledge systems are emerging.

1.2.3 Rationale for Mapping Sustainability

Given that the quest for sustainable development has become a global challenge, we need to converge on a shared understanding of the knowledge domain. This convergence requires a multidisciplinary perspective, spanning local to global levels as well as a range of very diverse forms and types of knowledge. More specifically, there are four imperatives shaping this mapping initiative:

Conceptually, while everyone recognizes that sustainable development is a holistic and integrative concept, there are considerable ambiguities pertaining to interconnections among various facets of human activities, to the constituent elements of sustainability, and to the proverbial matter of interlinkages. More importantly, there is as yet no overall view of the ways in which major forms of human activities generate problems that threaten social systems and natural environments or a coherent understanding of various solutions, socio-economic and political, as well as scientific and technical.

Disagreements also persist regarding the solutions to sustainability problems, and the conditions under which one alternative might be better than another. *Mapping Sustainability* is a step in the direction of intellectual order and coherence. It involves unbundling the knowledge content, and rendering a detailed account of issues central to sustainable development.

Strategically, mapping the knowledge domain of sustainable development is intended to help organize evolving knowledge about sustainability, and to make it more accessible for agents of change in public policy, business strategy, and creative ventures. It is also intended to facilitate access to cutting-edge analysis, innovative technologies, and multidisciplinary perspectives. We also seek to expand opportunities for knowledge provision and sharing through experimenting with different forms of collaboration and take into account diverse views and perspectives.

Operationally, mapping provides a set of rules for organizing existing knowledge about sustainability in ways that are functional as well as replicable. As such, it serves as a means of enhancing our understanding and reducing barriers to sustainable development. At the same time, mapping alerts us to situations in which the solution to one problem becomes, itself, the sources of another problem.

Functionally, to the extent that the mapping initiative is effective, it provides the foundations for the design of web-based capabilities for knowledge management, networking and sharing. It also enhances our appreciation of the details surrounding this domain of human activity helps to define policy responses and practices.

1.3 Frame System for Mapping Sustainability

Clearly articulated, the framing challenge is straight-forward: how best can we apply intellectual order to a domain of knowledge which remains *ad hoc* in its nature? In this book, we frame the domain of sustainable development, formulate a basic ontology, and derive rules for indexing knowledge materials in internally consistent and structured terms.

1.3.1 Frame and Ontology

Drawing on the work of Marvin Minsky – the founding Director of MIT's Artificial Intelligence Laboratory – it is useful to think of a frame as "a sort of skeleton, something like an application form with many blanks or slots to be filled" (1986: 245). Our framing challenge is to provide the skeleton within which to fill knowledge materials pertaining to the general subject of sustainable development. In so doing, we are developing the framework for articulating the parameters of sustainable development as a knowledge domain. Moreover, as Minsky reminds us, "[f]rames are drawn from past experience and rarely fit new situations perfectly. We therefore have to learn how do adapt our frames to each particular experience" (1986: 245).

The knowledge pertaining to the sustainability domain consists of the materials that are used to fill the slots. When the frame is fully articulated, and the slots are defined in sufficient detail, we can accommodate multiple aspects of sustainable development.

This way of thinking about knowledge representation is particularly useful in new domains, where the referent is of increasing importance to an every growing community of people and of countries, but where there remain considerable uncertainties and ambiguities about the nature of the slots, and about the items that should be used to fill in the blanks. The challenge now becomes one of deriving a knowledge-representation architecture.

Earlier in this chapter we put forth our operational definition of sustainnable development, and identified its fundamental conditions. Useful as that definition may be, it is still too general a statement to serve as anything other than delineating the nature of the framing challenge. The skeleton remains to be structured and the slots remain to be defined, so that the blanks can be filled. What is now needed is a set of rules for articulating a complete frame system, one that can yield an internally consistent ontology for sustainability.

Given the origins of ontology in philosophy and epistemology, it is often easy to overlook the operational implications for knowledge representation. In the context of devising a frame system for sustainability, the term ontology refers to the detailed description of concepts and sub-concepts, as well as relationships that represent interactions among entities associated with the domain. An *ontology* is a description – like a formal specification of a program – of the concepts and relationships that can exist for an agent or a community of agents. For our purposes, given the computational objectives, the term *ontology* takes on a specific operational meaning.

Consistent with the *mapping* objectives signaled above, the goals of ontology for sustainability are conceptual, strategic, operational and functional. More specifically, for architectural purposes, we need to articulate knowledge content with sufficient specificity as to enable computational representation which, when successful, then ensures effective knowledge sharing and management. The one critical ontology rule is that of respecting internal consistency in structuring the *skeleton* and then populating the *slots* – both italicized terms due to Minsky (1986).

The frame system yields an architecture structured as a set of nested and hierarchical relationships, or individual parts and coherent wholes. In terms of core principles, the representation of sustainability is anchored in three basic principles. The first principle consists of the definition of the individual *domains* of human activity (i.e. topics or conditions at hand). The second principle involves the specification of attendant *dimensions* spanning each of the domains (i.e. problem created and types of solutions proposed). The third principle of the frame system is an accounting of the *coordinated international actions* that are designed to steer, reduce, mitigate, or otherwise manage the challenges to sustainable development through the use of multilateral policy instruments.

We now turn to the content of the domain and dimensions, and their intersection (thus addressing the first and the second principles), and then we consider the types of coordinated actions among members of the international community in response to sustainability challenges (the third framing principle).

1.3.2 Domains

The point of departure for mapping sustainability is to select the core concepts (or topics) of interest. The goal is to be indicative and inclusive, not exhaustive or definitive. We show in Table 1.1 the differentiation of domains by generic type, yielding 14 distinct, but interconnected, aspects of human activities and conditions. Simplistic as this figure might seem, it is foundational in terms of conceptual architecture. It is an essential feature of the frame system, as it meets the requirements of the first design principle, namely identifying the specific domains of human activity to be addressed throughout the mapping initiative.

Table 1.1 **Domains of sustainable development.**

Demographic domain

- Population Dynamics
- Urbanization
- Migration and Dislocation
- Consumption patterns
- Unmet basic needs

Energy and natural resource domain

- Energy use and source
- Forests and land uses
- Water uses and sources
- Agricultural and rural activities

Technology-centered domain

- Trade and Finance
- Industry and Manufacturing
- Mobility and Transport

Domains of decisions and choices

- Conflict and War
- Governance and Institutions

Note that Table 1.1 shows only the first-order differentiation of human activity, the first step in developing ontology on ontology as a foundation for computation. As we proceed, we demonstrate how a set of disaggregation (or unbundling) rules allow for considerable refinement or granularity of representation or sustainable development domains without deviating from the core principles or the rules that connect them.

Figure 1.5 shows the same domains as in Table 1.1, however the display is different, and meaning is assigned to the difference. Figuratively, each topic constitutes a *slice* of the overall domain space. As we proceed, we will show how each of these slices (of core concepts) is further differentiated in terms of content-specificity and embedded in an integrated structure of knowledge representation. We will also identify the major problems generated by domain-specific types of human activities. In other words, we are seeking to identify the modal relationships between activities and conditions, on one hand, and sustainability problems that emerge as a consequence, on the other.

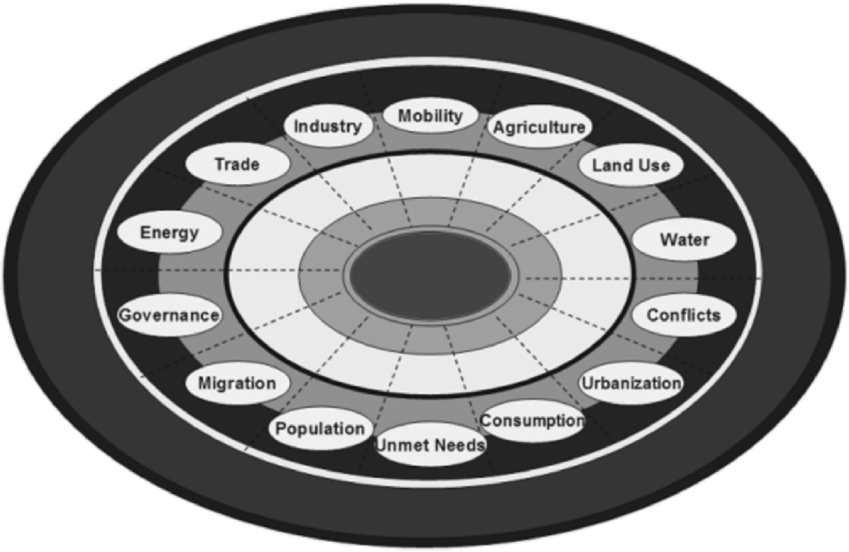

Figure 1.5 **Domains of the conceptual framework.**

Operationally, the forgoing means that we resort to the consistency factor in order to render the representation of the first principle (domains) consistent with that of the second principle (dimensions), both noted earlier. Retaining a consistency of structure across domains and dimensions allows us to build topic-specific ontology-segments that remain consistent across all topics addressed. At the same time, as we note further along, we must lift this restriction when incidents of coordinated international interactions transcend domains and dimensions. The restriction refers to the nature of the third principle, also defined earlier.

1.3.3 Dimensions

The next step is to specify the problems created by human activities that may threaten the viability of natural and/or of social systems and to delineate as specifically as possible the characteristic features of these problems. Conceptually, this means that the domains shown in Table 1.1 and in Figure 1.5 must be further disaggregated into a set of dimensions whose individual contents are customized to the realities of each domain of human activities. These dimensions are represented as a set of concentric circles, consistent with the embedded aspects of *Mapping Sustainability.*

The dimensionality issue refers to a specific design decision about select characteristics. For each of the individual domains, we seek to articulate the type of problems that are generated by human activities and conditions. Once the problems are identified, then we can take stock of the body of solutions available. In practice, the challenge of creating an ontology is to specify in some detail the contents for two broad classes of solutions. The first pertains to classes of Scientific and Technical solutions, and the second addresses Social, Economic, Political and Regulatory responses. In the context of Figure 1.5, the dimensions are depicted as *rings*, and the domains are depicted as *slices*. It is important to keep in mind that problems and solutions are dynamic, and will thus change over time. What might be regarded as a solution to one problem today may well be defined as a problem in its own right later on. Fundamental to the entire enterprise of knowledge development and representation is the expectation that the contents will change and that, under certain conditions, the underlying conceptual framework will also change. If the changes are substantial then the very fundamentals are called into question, and prospects of an entire paradigm change must then be raised.

A simplified view of the key dimensions is shown in Figure 1.6 for the 14 domains identified in Table 1.1 and signaled by the radial differentiations in Figure 1.5.

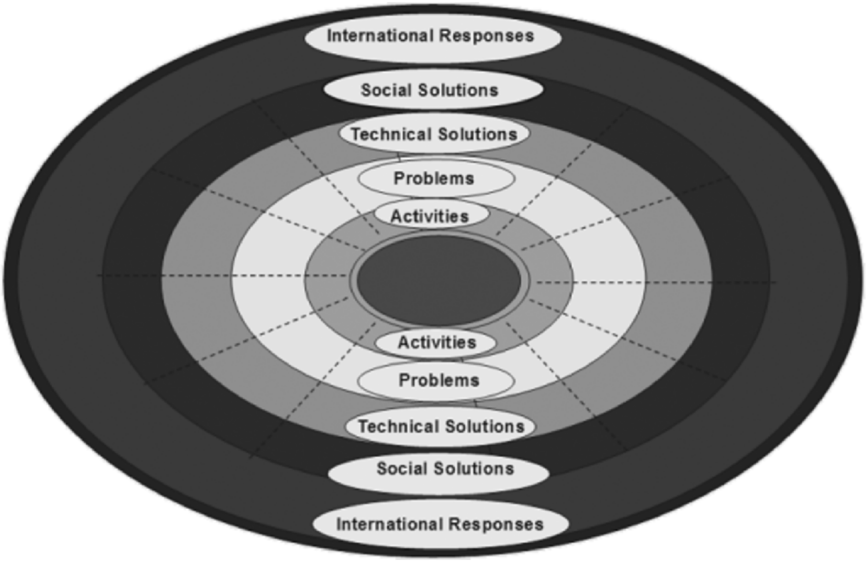

Figure 1.6 **Dimensions of the conceptual framework.**

So far, we have met the requirements of the first and the second principles for insuring a robust frame system, we now turn to issues at the intersections between domains and dimensions.

1.3.4 Intersections of Domains and Dimensions

Given the substantive coverage, the overall knowledge representation strategy can now be described in terms of domain representation and the hierarchical dimensions. Combining content around concepts in a hierarchical design yields the integrated framework, whereby each core concept (domain or topic) is extended in vertical and nested terms and thus connects domains and dimensions.[8]

With such considerations in mind, we proceed to disaggregate the knowledge contents for domains as well as dimensions of sustainability. This display is topic-specific, thus yielding 14 *ontology-contents* (or slices), which we show in Appendix A. Each topic array can be seen as representing the *table of contents* for the individual issue-areas. In other words, Appendix A shows the basic content structure in skeletal form for each of the 14 domains of human activities, thus addressing the dimensions-details as well.

Further along in this chapter we show the conceptual logic, as well as the operational logic, for representing the connectivity structure between domain and dimension – for each of the fourteen issue-areas. The connectivity properties are essential to the integrity of the knowledge-base as the essence of the nestedness lies in the intersection between domains and dimensions.

1.3.5 Coordinated International Actions

To complete the mapping initiative, we now turn to the third principle of the frame system by providing structure to the all-encompassing set of coordinated international actions designed to manage the damages and dislocations generated by human activities. In this segment of the knowledge-architecture, the contents of coordinated international as a new element in the design, namely the fifth ring.

This new feature encompasses and spans across the entire knowledge system of human activities, problems and solution types. With this move, the architecture departs from the domain-dimension structure of the nested system – whereby each domain of human activity is also characterized in terms of dimension-features. This ring is shown in Figure 1.7 and represents modal types of coordinated international actions. Parenthetically, the whitespace in the center indicates the location of Figures 1.5 and 1.6 (i.e. the slices and rings for the frame system) that meet the first and the second framing principles.

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[8] The details of the nested elements are described further along.

Figure 1.7 **Global sustainability strategies.**

The deviation from the design imposed by the first and the second framing principles (slice and ring) rests on the assumption that individual forms and types of international agreements cover a range of topics or elements within and across the nested system. Recall that, jointly, these two principles help ensure consistency or congruence of knowledge representation for the core issue areas addressed in *Mapping Sustainability.* This factor is a form of fragmentation-by-necessity. At the same time, it is only such for initial organizational purposes. The radials differentiating among the various domains of human activities are presented in broken, not solid, lines – as a rather reminder of this very important precept.

In terms of content, the third principle provides internal consistency needed in order to take stock of a set of generic forms of coordinated international responses that, individually and jointly, these modalities are designed to facilitate consensus towards sustainability, e.g. *Agenda 21*, various conventions and other new development mechanisms.[9]

[9] New development mechanisms include joint implementation and clean development, among others.

1.4 The Connectivity Structure

Designed to ensure consistency in the representation of content, the knowledge strategy for *Mapping Sustainability* is structured in terms of a hierarchically nested system. At this point, we show in some detail the architecture of the nesting logic, and the ways in which the first and second principles of design for the frame system are pulled together. The same conceptual specifications hold across all 14 substantive domains pertaining to sustainability. They provide an internally consistent, subject-driven, knowledge-management strategy.[10] Linkages across subjects are facilitated by a cross-referencing system.[11]

1.4.1 Framework Elements

The elements of the overall conceptual framework in Figures 1.5 and 1.6 present a broad view of the frame system and its design scheme. At this point, we put forth the formal definition for each key term.

Slice: Domain of Core Concept. A slice is a hierarchy of elements that constitutes the content features customized for each of the individual domains.

Ring: Dimension of Problem and Solution. A ring refers to specific aspects of issues, consequences, and responses, namely, (i) types of human activities and conditions associated with each general issue area, (ii) types of problems or dysfunctions generated by such activities and conditions, (iii) technical and scientific solutions proposed to date, and (iv) the socio-economic, political, and regulatory solutions.[12]

Cell: Granular Manifestation. A cell represents distinctive micro-level knowledge items at specific intersections of slices and rings (i.e. domain and dimension).[13]

1.4.2 Linkage System

The entire frame system – the knowledge structure – is integrated through its connectivity logic which defines how different pieces of the framework are

[10] Note again that the connectivity structure operates across first and the second frame principles, but not the third since the latter refers to actions that can target any item of slice or ring.

[11] The cross-referencing is done at the point of entry, in the Submit Site form, as discussed later in Part I.

[12] Figure 1.7 also includes an additional Ring in the system as a whole, namely that of coordinated international actions that transcend and cut across all of the domains of human activity.

[13] All of the above holds throughout the entire system structure, with the exception of the additional ring in Figure 1.7.

connected to each other and to system as a whole. This logic serves also as a mechanism to (a) guide the content-based indexing system and links the elements of the hierarchical system and (b) provides the computational protocol for knowledge management.

Accordingly, Figure 1.8 shows the nested linkages and the connectivity logic in generic form. This logic holds for each of the fourteen domains (i.e. topics, concepts, or activities). Thus, Figure 1.8 presents the generic linkage frame of the entire knowledge-base, for both conceptual as well as computational purposes.

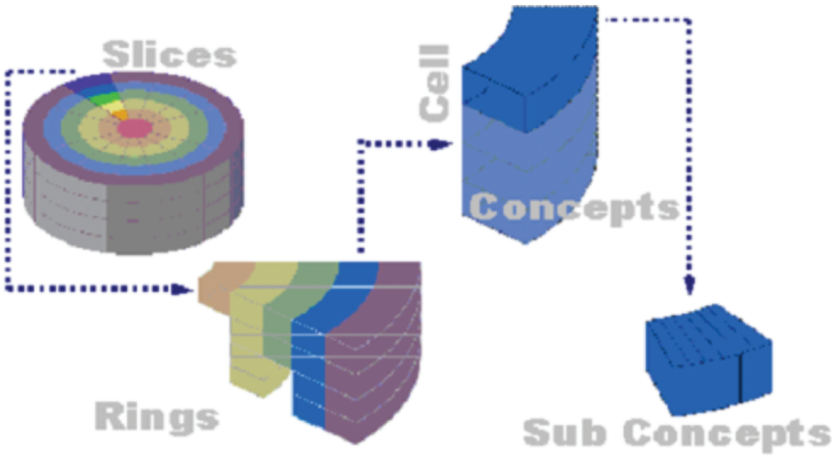


Figure 1.8 **Linkages across the conceptual framework.**

A view of the integrated frame system for domains and dimensions is thus derived by combining knowledge about the individual domains (i.e. concepts, types of human activity), with the attendant characteristics features. As to be expected, when the slots are filled – even in a first-order rendering – the display of content can be quite dense.

Figure 1.9 presents a simplified view of the knowledge-base, by that identifying the domains explicitly and noting the dimensions graphically. The multidimensionality of the conceptual frame is evident even in this aggregate representation. It is useful to note that this design is generic in the sense that it can be applied to any issue-area or problem of interest. For example, if we consider the domain of industry, we can then differentiate among different types of facets of industrial activity in considerable detail, while still adhering to the basic conceptual framework.

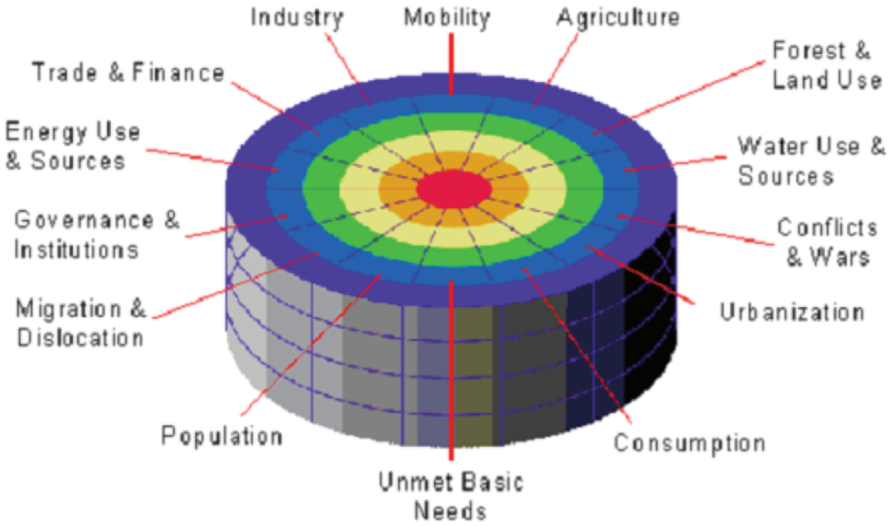


Figure 1.9 **View of domains and dimensions.**

As presented here, Figure 1.9 can accommodate any structured knowledge domain or knowledge content. This feature greatly facilitates the task of customization for meeting individual user demands for different content-representations versions.[14] The design as a whole can be modified by adding or deleting individual slices and rings.

1.5 Integrated Knowledge Content

At this point, we turn to the challenging task of content display and the representation of substance representation. The challenge lies less in the formulation of content, since it is essentially rule-derived, and instead in accommodating the constraints of the hard-copy printed page in the physical form, venue.

The display of content for the knowledge domain of sustainable development, shown in Figure 1.10 consists of the slots of the frame system, the slices and rings, filled with the appropriate content. Figure 1.10 is thus the combined representation of Figures 1.5 and 1.6 with all of the content-items integrated therein.

The purpose of Figure 1.10 is to show the derivative nature of the frame system (and its hierarchical and nested logic). Guided by the theoretical constructs noted earlier, each entry refers to a specific knowledge item at the

[14] The generic quality of this design for organizing knowledge will be demonstrated in Chapters 10 and 11.

intersection of a domain and a dimension. The elements of international relations and global accord (the fifth ring) are not represented in this view, but given the complexity of content, it does not provide the same level of granularity as the above two display methods. Earlier, we referred to Figures 1.5 and 1.6 as representing a first-order accounting of knowledge content. Put differently, this means that the display shows only the higher-level entries in the ontology, and not the derivative or detailed specifications. At this point, we turn to the representation of the knowledge system as a whole. A more detailed representation of the knowledge domain is shown in Appendix A.

1.6 The Value of *Mapping Sustainability*

Earlier in this chapter, we noted some basic reasons for engaging in mapping sustainable development as a knowledge domain. Having presented the logic, as well as the design principles of *Mapping* – addressing principles, structure, and architecture – we now turn to a fundamental query, namely, what is the value-added of this initiative?

By way of summary, we note elements of value-added due to the *Mapping* initiative.

One: *Mapping Sustainability* provides an internally consistent baseline of sustainable development. The science of sustainability is at an early stage of development; therefore this baseline consists of a systematic representation of the constitutive elements.

Two: *Mapping* is based on the application of a multidimensional ontology designed specifically to represent key aspects of the issue-area at hand, including attendant complexities and interconnections. *Mapping* provides not only an insurance against the temptation to engage in undue simplification, but more important, a systematic view of what must be taken into account when addressing any single domain or dimension.

Three: Conceived and written in English, the terms used throughout *Mapping Sustainability* are commonly understood by English speakers. The definitions of concepts is intended to interject a degree of precision in understanding, even when the subject itself can be interpreted differently by different communities of knowledge, policy, or practice.

Four: When *Mapping Sustainability* is rendered in another language, we generally assume that the various concepts are portable and that each language does in fact have a corresponding term. This assumption is simply wrong. In Arabic and in Chinese, for example, the sustainable development substantive vocabulary is not as fully developed as in English. This has required us to help formulate the equivalence for the terms and concepts in question. The result is as reliable a multilingual rendering of key elements of sustainable development as is currently possible.

Five: The ontology, in conjunction with and the companion GSSD Glossary of explanations and definitions, serves also as an indexing system to categorize e-materials of relevance with various degrees of granularity or detail.

Six: Computationally, the elements of the ontology consist of the tags that assign knowledge-content to the appropriate slot. The assignment process is an ongoing activity. To simplify, however, this means that when the assignment-to-slot is completed for an item, it is then incorporated in the overall knowledge-base.

Seven: The repository for the knowledge-base on sustainable development is an integral part of GSSD, and it is available for different types of uses. For example, some users may draw upon the materials for teaching purposes, others for public presentations, still others for knowledge development, and so on.

Eight: Since the ontology serves as a provider of topics identifiers and outlines for diverse purposes, it also serves as a mechanism for tracking changes in understanding and evolving knowledge over time. It is something of a 'net' (in the most literal sense) to help track evolving knowledge over time.

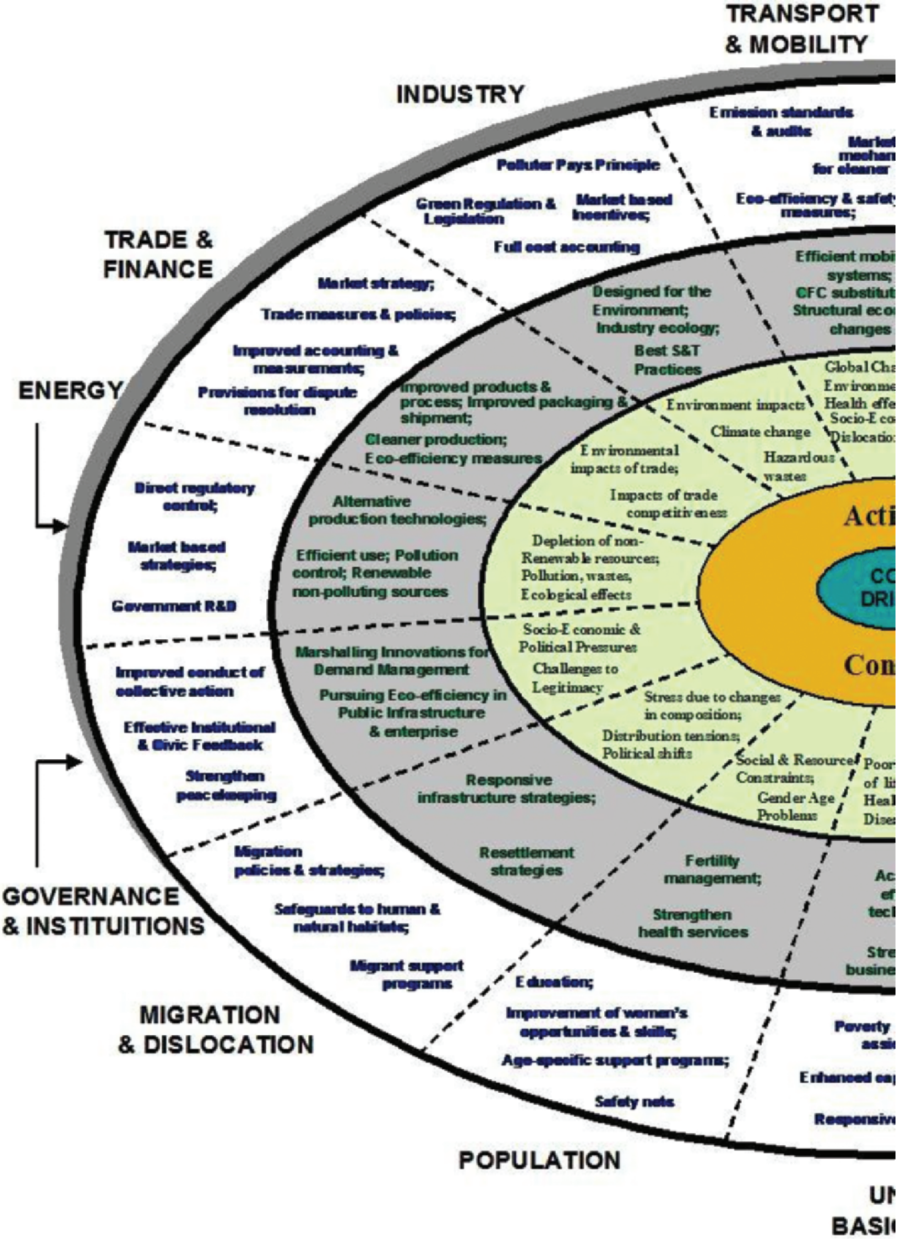
Nine: *Mapping Sustainability* provides also the knowledge platform for the provision of local content, i.e. knowledge generated at the local or various sub-national and national levels around the world. Routed through GSSD, such local knowledge represents the 'voices' of communities that are not often expressed in cyber venues that, to date, remain dominated by inputs from advanced industrial countries.

Ten: The design of *Mapping* – and its application for knowledge management – consists of the common organizing principles and represents the shared understanding that guides e-networking among a set of actors and agents converging around sustainable development as a knowledge domain.

1.7 End Note

Mapping Sustainability is the first step in the broader computational strategy for reducing e-barriers to knowledge pertaining to sustainable development. It is the foundation for generating a shared understanding of content and provides the fundamentals for engaging in e-networking to enhance both content and value of knowledge. The fundamentals of computation are predicated on advances in information technologies. And the fundamentals for reducing knowledge gaps are based on enhanced knowledge e-networking practices and strategies.

In Chapter 2 we show how *Mapping Sustainability* is transformed into a computational frame for global knowledge e-networking. We demonstrate


TRANSPORT & MOBILITY
INDUSTRY
TRADE & FINANCE
ENERGY
GOVERNANCE & INSTITUITIONS
MIGRATION & DISLOCATION
POPULATION
Emission standards & audits
Eco-efficiency & safety measures;
Polluter Pays Principle
Green Regulation & Legislation
Market based incentives;
Full cost accounting
Market strategy;
Trade measures & policies;
Improved accounting & measurements;
Provisions for dispute resolution
Direct regulatory control;
Market based strategies;
Government R&D
Improved conduct of collective action
Effective Institutional & Civic Feedback
Strengthen peacekeeping
Migration policies & strategies;
Safeguards to human & natural habitats;
Migrant support programs
Education;
Improvement of women's opportunities & skills;
Age-specific support programs;
Safety nets
Designed for the Environment;
Industry ecology;
Best S&T Practices
Improved products & process; Improved packaging & shipment;
Cleaner production;
Eco-efficiency measures
Alternative production technologies;
Efficient use; Pollution control; Renewable non-polluting sources
Marshalling Innovations for Demand Management
Pursuing Eco-efficiency in Public Infrastructure & enterprise
Responsive infrastructure strategies;
Resettlement strategies
Fertility management;
Strengthen health services
Environment impacts
Climate change
Hazardous wastes
Environmental impacts of trade;
Impacts of trade competitiveness
Depletion of non-Renewable resources;
Pollution, wastes,
Ecological effects
Socio-Economic & Political Pressures
Challenges to Legitimacy
Stress due to changes in composition;
Distribution tensions;
Political shifts
Social & Resource Constraints;
Gender Age Problems

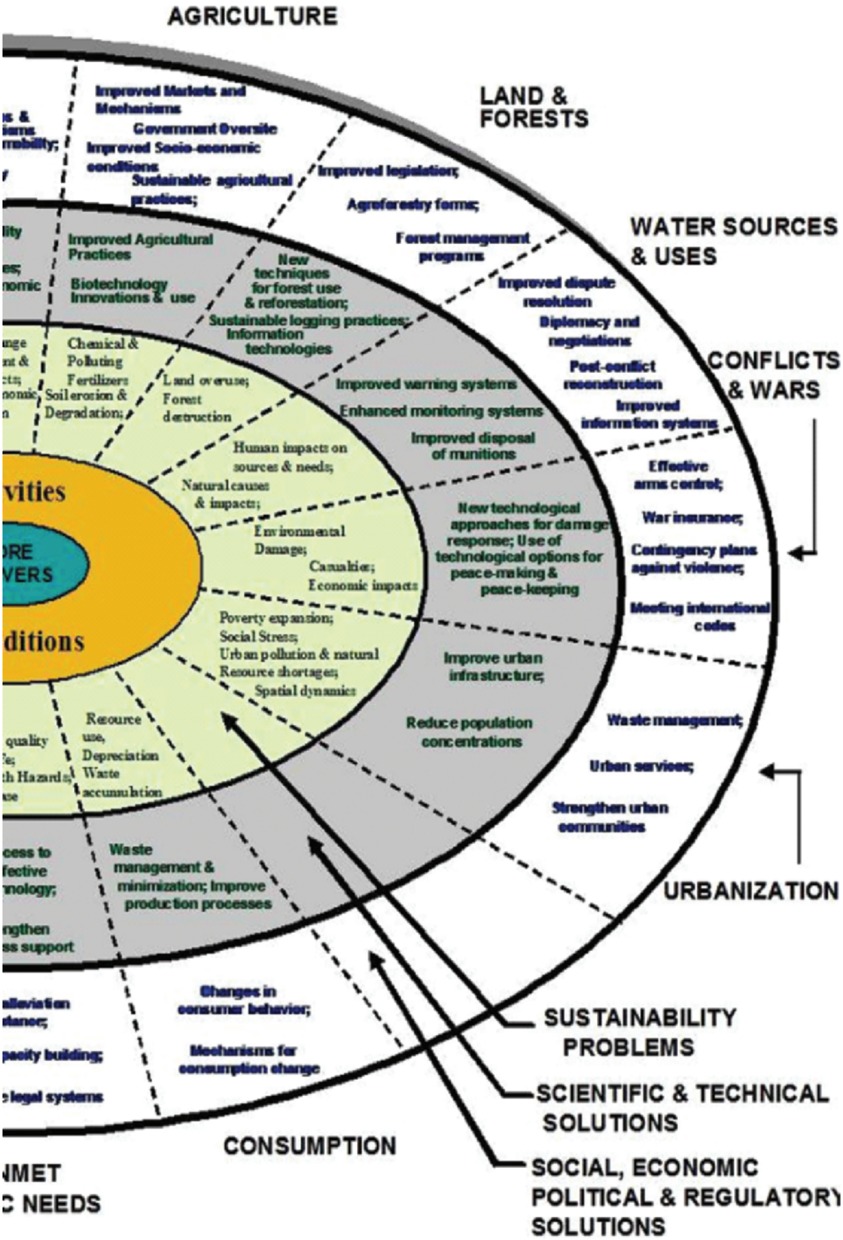


Figure 1.10 **Overview of integrated knowledge domain.**

the principles guiding computability of GSSD as an interactive web-based e-knowledge networking system, GSSD. The goal is to facilitate access to, and provision of, knowledge bearing on transitions toward sustainability. More specifically, the challenge we address is to reduce e-barriers to knowledge access, provision, sharing and distribution worldwide.

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