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■ *Research Paper*

A Transdisciplinary World Model

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The complexities and non-linearities of the world system are increasing the mismatch between the way we think about the world and the actual behaviour of the world. In systems science, this is summarized by expressions like unintended consequences, counter-intuitive outcomes, emergent properties, synchronous failures and unpredictable knock-on effects. This whole field has been summed up as the global problematique. Increasing the match between our espoused world models and the behaviour of the real world in policies, strategies and decisions requires a major shift to holistic transdisciplinary approaches.

This paper will describe the innovation and pilot testing of a transdisciplinary approach to stimulating systemic interconnected thinking about complex issues from the global level (for example climate change) to the local level (for example increasing resilience in a village community). The approach is based on a world system model that is designed to promote holistic and transdisciplinary conversations across 12 key dimensions of sustainable communities. The model serves several purposes ranging from a 'World Game' that groups of people can play to strategic workshops that challenge decision making beyond conventional scenario planning methods, to ways of mapping global impacts of climate change.

The paper will describe some of the main foundations from systems thinking that underpin the model. These include multi-factor modelling, variety engineering, feedback coupling and non-linear behaviour. Some indications of application are also given.

Keywords transdisciplinary; problematique; mental model; systems thinking; world game

'A question of great scientific interest and perhaps grave importance is whether the information processed through consciousness is adequate and appropriate for the task of human adaptation. '(Bateson, 2000 p. 446)

The dominant culture and practices of science are based on some form of reductionism in which explanations of complexity are constructed from analysis of parts. Those emerging sciences that attempt understanding of complexity without reductionism are at an early stage of development. This makes the practice of transdisciplinary work difficult for those in management and policy who are most embroiled in complexity. Laudable

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though evidence-based policy is, the problem here is that the evidence is largely accumulated from fragments and slices of the complexity that the policy maker is supposedly dealing with. Working across disciplines is often like a mix of people of different languages and cultures who have to work very hard at finding a common language. Even with such communication codes emerging, the differences of specialized understanding may make it impossible to find non-trivial common ground. This creates three layers of difficulty for the policy maker—the complexity itself, the confusion of disciplines and the intelligibility to policy makers of the knowledge and advice generated.

A helpful diagnostic idea from cybernetics is provided by Bateson (2000, pp. 446—553) in discussing the effects of conscious purpose on human adaptation. His argument is summarized in Figure 1.

Beginning at the top of the diagram, narrow specialization has the effect of cutting out perception of the wider world. Appreciation is narrowed by focused selection. This has the effect of cutting off appreciation of the wider pattern that connects. At some point, the variety of the actor is in serious mismatch with the variety of the environment. Any feedback from the environment is only adapted to in the context of the entrenched worldview. The next step is an amplification of that distortion through the rapidly expanding application of powerful technologies. The complexity of the wider environment then feeds back with an escalation of crises. The additional danger is that the cycle continues as more of the same is applied to try and resolve the crises.

As a contribution to redressing the imbalance of specialization in relation to the global problematique (King and Schneider, 1991), I have been experimenting with the introduction of designed mental models as a way of creating an arena for a participative approach to encouraging transdisciplinary insights. The focus has been on fundamental issues of sustainability and resilience in a complex and rapidly changing world. This paper introduces the systems thinking behind this work which has been applied in an unconventional way to create powerful synthesis events. The designation of this conceptual tool is the *world system model*.

The world system model combines several vantage points on the global problematique in order to understand better the complexities of the social ecological system in which we live. However, these perspectives deliberately avoid

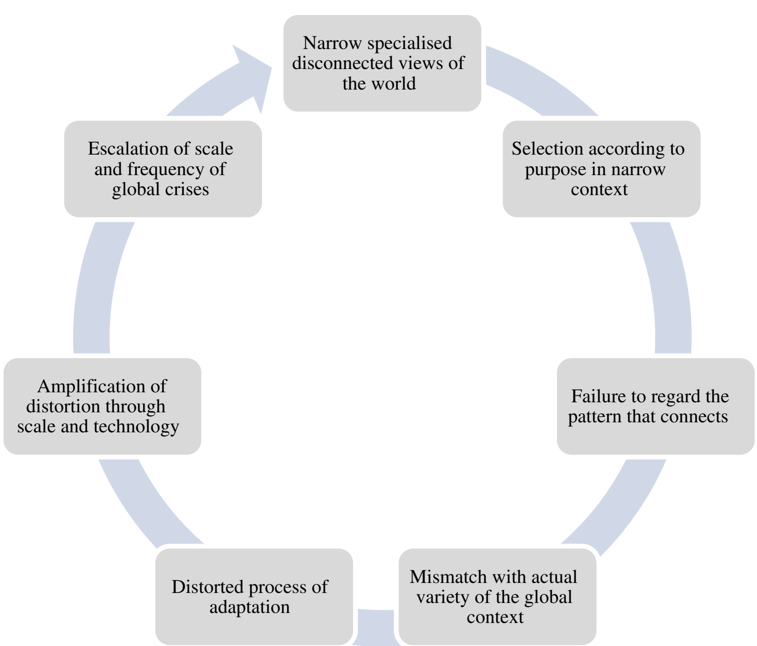

Figure 1 The distortion of human adaptation to environmental complexity

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the usual subject categories that tend to determine disciplines such as economics, ecology, engineering, and politics. Instead, very simple terms related to a set of critical components of humans surviving and thriving on planet earth. These perspectives are deliberately combined into an interconnected whole to further emphasize the holistic nature of the field of concern. The model serves as an organizing principle for information about past, present and future and as aid to creating scenarios that require the integration of multiple perspectives. The model also provides a framework for different forms of meeting procedure to facilitate cross-discipline conversations and the search for the profound simplicity after complexity.

A holistic approach needs also to include those concerned in sharing the thinking and therefore cannot be managed by the processes of scientific enquiry alone. Transdisciplinary work requires the conditions to enable the 'trans' to really take place. This is a task of well-designed and conducted facilitation. In designing processes and events that combine the objective and the subjective, three perspectives need to be integrated.

One of these perspectives is the common one that there is a 'world out there' about which we have information and knowledge. A second perspective is the interpretive perception of any given participant in a project or event. The third perspective is the manner of representing and relating the information on the 'world out there' to the 'world in here'.

Perspective 1: Most modern science adheres to the principle that the observer is distinct and separate from the observed, and hence, there is the possibility of creating an objective model of the observed world. Such models can be used for making estimations and predictions of how the world is likely to behave. From this perspective, best policies are based on empirical evidence, preferably peer reviewed. The empirical evidence accumulates as information of varying degrees of granularity that form descriptive elements of the world. If this is the sole perspective, then little attention is paid to the sociology and psychology of the policy makers themselves. It also has the characteristics of 'driving in the rear view mirror'. This is also described as first-order cybernetics.

Perspective 2: A contrasting perspective is that the world we see is also a function of the way we see it. This is described as second-order cybernetics (von Foerster, 1995). Therefore, understanding a situation is also an act of perception which creates a gestalt, a sense of the whole which is being regarded. Thus, there may be many ways of seeing the world conditioned by culture and habit but which are taken for granted. These may not be up to the task of dealing with contemporary complexity. The development of new cognitive skills of patterned thinking is required.

Perspective 3: The critical reconciling factor is the manner in which the perception is both represented and developed towards greater integrality. This is popularly referred to as a 'mental model', as distinct from an external model. Both the construction of the representation and the gestalt it forms have a strong effect on the understanding and engagement with the 'world out there' and the meaning of any relevant information.

The three perspectives themselves constitute a dynamic system as represented in Figure 2.

The following description and analysis deal with the third factor of conception of representation. One of the key inputs to considering ways to represent the global problematique is from the work of King and Schneider (1991). They attempted to represent the interconnected variety of world problems as a whole as a higher order of complexity referred to as the *problematique*. Critical to this conception is the observation that solving problems in isolation obscures unavoidable unintended consequences arising from the interconnectedness of everything. A complex of solutions that took this into account with greater possibility of problem reduction is what they termed the *resolutique*, a term introduced by the Club of Rome (King and Schneider, 1991, pp. 183–192). Gregory Bateson (Bateson, 2000, p. 502) proposed a systemic definition of a future viable world resolutique as follows:

> 'A single system of environment combined with a high human civilization in which the flexibility of the civilization shall match that of the environment to create an ongoing complex system, open-ended for slow change of even basic (hard-programmed) characteristics.'

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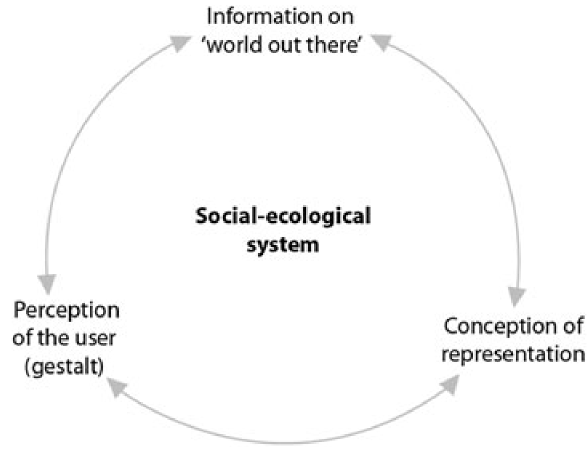

Figure 2 The resonant threefold system of conception, perception and information around the social ecological system

The world system model I developed (Hodgson, 2011) is a visual symbol that has been designed to evoke a different gestalt from the usual fragmented or specialized perspectives and in so doing enables a different understanding of the world, what we know about it and how to act in it. A version of the symbol is shown in Figure 3.

These are the main features to be noted.

- It is a set of 12 interdependent mutually relevant *factors*, each factor indicating a component (referred to as a *node*) in the system essential for viable human life in the context of the earth system.
- The 66 *interconnections* mean that a change of state in any given factor may trigger, induce or otherwise modify a change of state in another factor.
- Each factor has a *condition* which is the state of health or viability at a given time.
- This condition is not static, but it is changing and thus reveals a *trend* or direction of change.
- The direction of change may be towards *increased* viability or *decreased* viability.
- A trend may accelerate or change direction such that it becomes a *discontinuity* which generates a shock or surprise. This could be positive or negative in relation to viability. Common terms

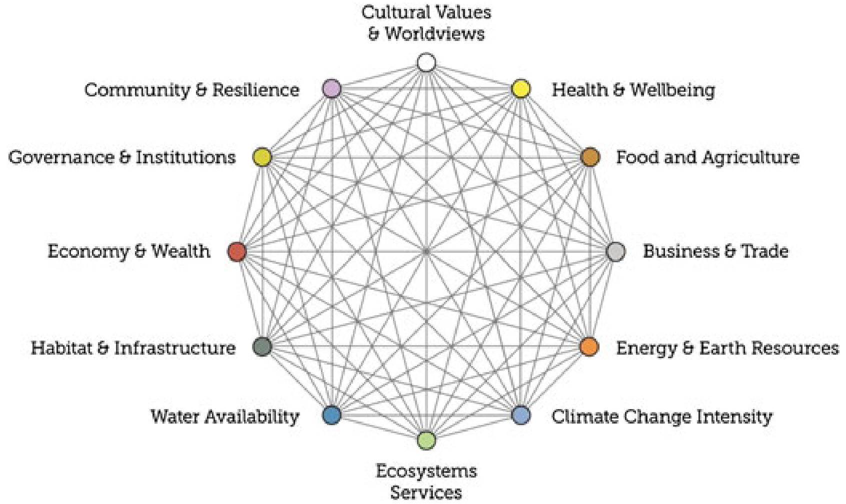

Figure 3 The world system model

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for discontinuities are *trend-break*, *tipping point*, *peak* and *runaway condition*.

- Discontinuities in a given factor often have greater cross impact on other factors and can create a *domino effect* in which the effects ripple throughout the system, causing multiple parallel discontinuities. There are counter-intuitive instances where actions in one node, seen as solutions when viewed in isolation, actually create problems in other nodes if these are disregarded and there are not synchronous adjustments.
- It is possible that multiple discontinuities may occur simultaneously without interaction or direct causal connection. This can lead to *synchronous failure* (Homer-Dixon, 2006) or *synchronous success* in terms of overall world viability.

The 12 nodes are greatly expanded in the full version of the model. These can be referenced elsewhere (IFF, 2012). The discussion which follows concentrates on some of the principles from systems thinking that inform the model and contribute to its effectiveness as a catalyst for transdisciplinary engagement with the complexity of sustainability and resilience in human social ecological systems such as villages, cities, and bioregions.

CYBERNETIC ANALYSIS

A key concept in cybernetics is *variety*. This is the number of possible states of a system. Needless to say, the number of possible states in the actual world system is astronomical. Ashby's Law of Requisite Variety (Ashby, 1958) states that only variety can absorb variety. Yet, we humans with low variety governance claim to 'run the system'. In cybernetics, variety engineering is the skill of designing regulation and feedback such that requisite variety is achieved. The term *requisite* implies that absolute matching is not necessary (or feasible) but that there is a minimum complexity required in the regulator of a system. If this is not the case, the regulator is too simplistic, then its intended control actions are likely to make the system more out of control. The areas of diversity that are interacting and need to be regulated are matched by a commensurate diversity in the guidance system; variety attenuation must be intelligently designed.

This point is very critical when we consider the resilience of social ecological systems. Applying the Conant–Ashby Theorem (Conant and Ashby, 1970), that 'every good regulator of a system must be a model of that system', we are faced with the challenge that, whether we are considering a city or the whole planet, resilient governance should require extremely well-designed governance models that are based on consideration of the whole as a system. Of course, in extremis, that would take the world to regulate the world. Dror (2001) has pointed out that the capacity to govern on current models and practices is taxed beyond its limits. Apart from considerations of the quality of those who lead, he points to rapid non-linear change, increasing uncertainty and inconceivability and multiplying complexity. The implications he summarizes as follows:

> 'Consequently, before identifying the tasks of governance and working out required redesigns, we need to look at the environments within which governance will have to operate in the foreseeable future and the problem domains with which it will have to cope.' (Dror, 2001, p. 38)

Stafford Beer (Beer, 1974) pointed out very clearly that the manner in which governance is structured is ill suited to real world complexity.

> 'We discovered that viable systems are bombarded continuously with high variety stimuli, the variety of which has to be attenuated if the system is not to be overloaded. The attenuation must be done according to a pattern, if it is not an arbitrary discord. If that pattern is to have survival value (which is a necessity for a viable system) then it must be a regulatory model of whatever is regulated. Then it follows it has to be a *central function* of the system, because only the system as a whole can have a model of its own relationship with its own environment.' (Beer, 1974 p. 71)

If we apply the reductionist paradigm of splitting into parts and solving the parts, hoping we can put them together and guide the whole system, we are not only mistaken; we are set up

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in this current world to make things worse. 'All the king's horses and all the king's men couldn't put Humpty together again'. The Conant–Ashby theorem implies that the variety and complexity of the regulator must to a sufficient extent match the actual structural complexity being guided. This may seem like a tall order, but this is not a counsel of perfection; rather it is an indication of a direction of improvement from an overly reductionist approach and a call to improve our design of governance for increasing resilience in a rapidly changing world.

One of the observations that motivated the development of the world system model was that even quite obvious relationships between things in the world system are treated in separate compartments and not considered together. For example, only recently have climate change and energy security been seen as related. It is emerging that energy and food are highly interdependent as are energy and water. It is also clear that society is having great difficulty in connecting social behaviour, such as consumerism, with peak resource issues and untenability of continuous economic growth on a limited planet.

The requisite variety of the world system model derives from the combination of the 12 nodes and the significance of the 66 interconnections. Some basic statistics of the model indicate how it generates variety. Here is a basic analysis.

Suppose that each node can be changed by one of two kinds of policy, *helpful/unhelpful*. This indicates that the number of possible input states of the system is 2^{12}, which equals 4096. Even on a binary input model, we know that the nodes are interconnected. Formally, everything is connected to everything else, but we also know in the real world that connections vary in quality and intensity. The state of any node might have an effect on every other node; that is, it can affect 11 other nodes, thus making up the 66 connection lines. These resultant effects are not necessarily equal across all the connections.

Applying an assumption that any connection liner may be active (or not) and that potentially any pattern amongst the 66 lines might exist, we end up with an astronomical number of possible states of the system, namely $66! = 544 \times 10^{90}$. This indicates the scale of world complexity since even this is an oversimplification. However, not all states are significant; the problem is how do we anticipate for the future which ones are? There are different ways this variety is reduced, the most severe form being linear causal prediction or projection. There are more sophisticated ways of approaching this variety.

Scenario impact thinking reduces the astronomic variety by picking a number of combinations of node states to provoke thinking about what different states of the world that might generate. Often only two independent states are picked which, with binary outcomes, can give four future scenarios. These states can then be used in 'wind tunnelling' policies and strategies for resilience.

The ability to handle variety can be extended with the world system model. For example, different combinations of active interconnections where discontinuities or trend breaks are likely to happen generate different anticipatory scenarios. For example, taken in combinations of 3 nodes out of the 12, there are 220 possible scenarios that could be generated. Again, taken in combinations of 5 nodes, there are 792 possible scenarios. This demonstrates that the model has a much higher variety than a simple list in which the only variable is the order with no combination where the possibilities are only 12. In practice, even the investigation of three or four of these combinatorial scenarios is a powerful way of expanding contingency awareness, or the present moment of the investigator (Hodgson, 2013).

As an illustration of the world system model for capturing patterns of interaction, it was used in an experimental investigation of how to map the impact of climate change in different parts of the world in a systemic manner (Hodgson *et al*., 2011). The scope of this work is beyond this paper, but an illustration will give a hint of the method. The example in Figure 4 is an application to summarizing the current literature on the potential impact of climate change on the Indian Subcontinent as viewed through the lens of the world system model.

The world system model is essential, similar to that in Figure 3 except that the size of the circles (nodes) is scaled to a simple estimate of the intensity of impact interpreted from the literature. The remaining nodes are clearly implicated through

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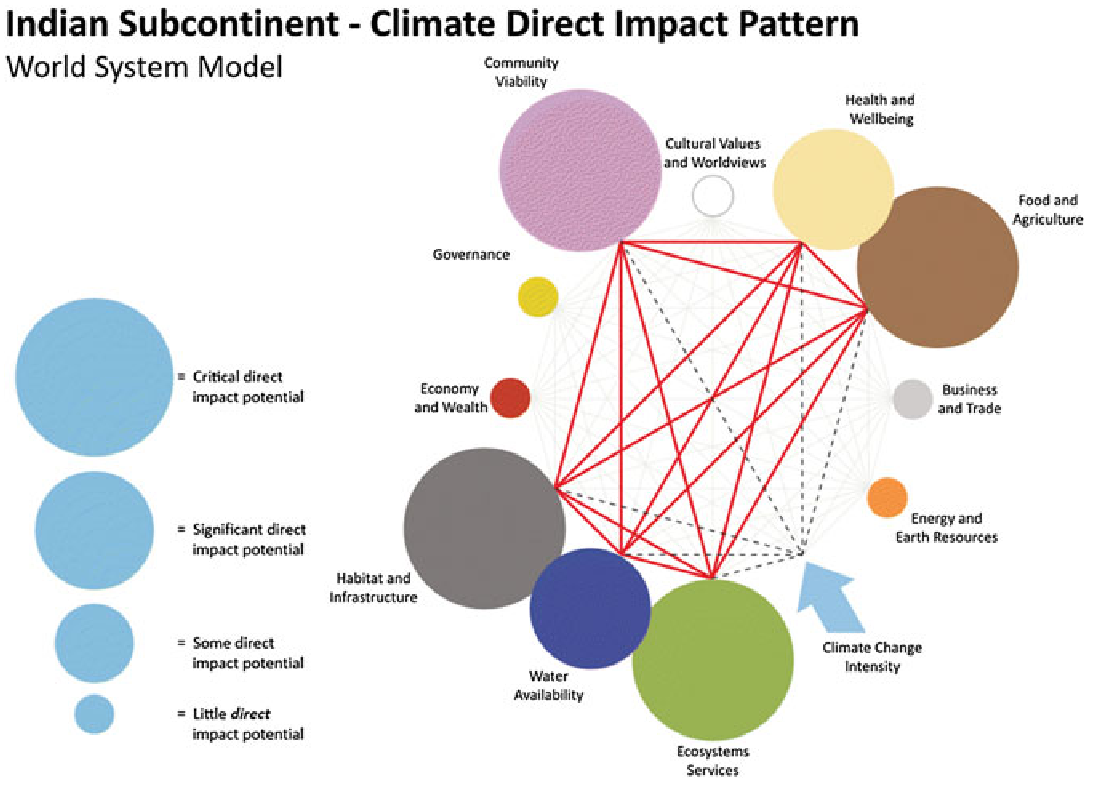

Figure 4 The world system model used with nodes sized to indicate degree of impact of climate change. The highlighted (red) lines indicate important possible reciprocal or knock-on effects between impacted nodes

additional connections, but a division is made between the primary and secondary impact nodes. The red lines indicate the multiple interactions that make of the system complexity and contribute to the overall vulnerability. In this example, there are 15 two-way connections.

There are many additional ways in which the world system model may serve as a transdisciplinary tool for investigating the global problematique. In building world system appreciation, investigation of each node separately is *first-order* interpretation. This includes a compilation of the important trends and possible discontinuities for each node.

Interactions between any two or more of the other node factors create a more complex picture in which the combination creates a synergetic effect. These are *second-order* interpretations. The situation created or scenario implied is a synergy and not the result of a simple addition of the parts.

Third-order effects are where these sub-complexes can be viewed as systemic structures which produce a behaviour over time not explicable by any set of trends alone. For example, this might be a feedback situation that can be modelled with system dynamics. Third-order effects may indicate a situation where other types of modelling and simulation could be instructive, using the world system model as a generative platform. These different orders of coupling are further described in the section below on research.

COGNITION, LEARNING AND COLLECTIVE INTELLIGENCE

Interaction between people and the model is reflexive behaviour influenced by the acceptance, modification or rejection of the mental model and its data. Actors using the model

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create a world interpretation. These *fourth-order* effects are generated in the participatory engagement with the model and the various conversations stimulated between the people in the engagement, which might be a project, a workshop or, very effectively, the IFF World Game (Hodgson, 2011).

The world system model diagram is, to the active eye of the beholder, a gestalt. It is a holistic pattern that holds together a wide diversity of factors and helps the mind hold attention on a bigger picture. Psychologically, the familiar pattern of the circle enables a complex pattern to stabilize in people's minds in a recognizable and even comfortable way. This is reinforced by the presence of 12-ness in different aspects of Western culture from clock faces to zodiac signs. In Eastern cultures, a similar approach occurs in the use of *mandalas* and *yantras*.

The diagram, in its simplicity, is also generative. It enables people to organize their thoughts and, through juxtaposition, to generate new ones. For example, taking any two nodes together as a challenge, we can ask what would resolve that combinatorial challenges, and new 'third perspectives' are generated. This can range for basic problem solving to wider synergistic understanding. This combinatorial interaction between discipline and responsibilities is critical for its catalytic function for transdisciplinary work.

The diagram also provides a background within which people can focus their issues of concern. Placing the question or task in the centre of the model enables combining of attention to the focus and attention to the whole. In gestalt terms, this is the construction of a figure/ground perceptual field. It enables holism with focus.

The diagram also has a property that links gestalt and recursion, analogous but distinct from that present in the Viable System Model (Beer, 1985). It can be applied at different scales and levels. This means that there can be a stable or invariant frame of reference and meaning that can help scale linking in tackling complex multi-levelled challenges. Conversations between levels (e.g. village, town, bioregion, city) are enabled by the common frame of sustainability and resilience which they each share.

Further Research and Innovative Learning

This work is at an early stage of development. Applications so far have been in two broad areas. One is the incorporation of the world system model in strategic and policy workshops in areas including public health and leadership development. Another has been in the development of the IFF World Game (IFF, 2012) as a form of exploratory and creative engagement in large-scale difficult issues. Especially interesting is the application to complex areas such as public health (Hodgson, 2011, p. 60).

From a systems perspective, some clear research themes are emerging.

(1) Horizon Scanning—methods of scanning trends and potential discontinuities to keep refreshing the core information briefings. This needs to be a collaborative effort with partners and requires a networked web platform dedicated to this function. One pilot application already mentioned was as support to the UK Foresight project on the impact of climate change (Hodgson *et al*., 2011).
(2) Transdisciplinary Decision Making—identifying and studying second- and third-order interactions across the 66 connections in the model. This is as yet unpublished work of IFF.
(3) System Dynamics—cybernetics and systems theory are core to understanding that the world system is a dynamic system. There is need for a project that elaborates the nature of the model in cybernetic and feedback terms using such concepts as requisite variety and variety engineering, structural coupling, emergent properties, reflexive or reentrant systems, viable systems theory and others.
(4) Multiple Levels of Connection—investigating further the meaning of different orders of connectedness. These are summarized as follows:

First-order effects are those which occur within a given parameter. Especially of interest in the modelling are discontinuities or tipping points. An example in energy would be peak oil.
Second-order effects are interactions between any two or more of the other factors which create a more complex aspect of the overall problematique. An example is that abundant

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cheap energy (desirable for a number of good reasons) also carries the knock-on danger of over-pumping of aquifers, grid locked mobility, and appropriation by despotic military and terrorists. Third-order effects are where these sub-complexes of tangled issues create a new dynamic, which has escalation feedback and perhaps needs something more like system dynamics to explore possible outcomes.

Fourth-order effects are the reflexive behaviour of humans in society to the manifestations and outcome of the complex emergent behaviour and which may further exacerbate or remediate the conditions arising. At this level, the search is for decision support methods that increase the quality of *decision integrity*, which takes into account the ethics and responsibility of choices in regions of high uncertainty and low predictability (Hodgson, 2010).

The complexes of solutions to problems-in-combination, termed the *resolutique*, will be an emergent property of factors way outside our control. Any single-issue approach is doomed to failure from unintended consequences. Combinatorial thinking will do better but must be a humble and learning approach. This model is not a panacea or silver bullet—simply a practical contribution towards more holistic methods. We need a comprehensive revolution in thinking if we are to have a policy approach that intelligently matches the global world with requisite variety.

(5) Recursion—the holistic world system model will take on different characteristics depending on what perspective is adopted (e.g. global, political regional, bioregion or local city or village). It will also be coloured by the cultural context. This needs a much richer articulation of the nodes and interconnections based on factual research.
(6) Futures Thinking—there are three purposes for the development and application of the world system model. One is to provide and integrative mapping of the current situation. This is exemplified in the version in Figure 3. The second is as a basis to facilitate more integrative innovations for tackling specific challenges. Initial work, for example, is being done in relation to urban design. The third purpose is as a framework for envisioning options for human lifestyles that are consistent with one-planet living. This combines the model with the concept of three horizons in futures thinking (Sharpe and Hodgson, 2006; Curry and Hodgson, 2008).
(7) Techniques of Visualization—the geometry of the model is abstract. It needs to be linked with concrete visualization of organizations of data. This needs to migrate into 3D and be based around the icosahedron as in syntegration (Beer, 1994). The icosahedron has 12 nodes and therefore can represent a three-dimensional version of the world system model. This would be greatly aided by the development and use of suitable visual and data base software methods.
(8) Advanced Facilitation—strategy workshops and group games require facilitation expertise, either in person or built into the rules of engagement and the design of materials. A practical facilitation laboratory to try out new options is one way to accelerate this. This is especially the case when the model moves into 3D. The development of the skills and capability in this area leads to the development of praxis capabilities (Hodgson, 2011, pp. 75–80).
(9) Creative Gaming—the military have for decades used the 'war game' as a way to visualize and engage with interactive combat. There is rising interest in the game as a positive simulation and rehearsal of dealing with complex situations. This is used in emergency and disaster training. The development of positive games to enable better ways of tackling complex and innovative transformations has a long way to go. A pioneering example is the world game designed by Buckminster Fuller (Buckminster Fuller Institute, 2012). Some of the positive values of 'playful gaming for serious results' are as follows:

- The creation of a safe place to explore, learn and work things out
- Scope to design better alternative worlds
- Giving a focus, objective and boundaries for practical outcomes
- Suspending the unhelpful rules of customary life by entering 'the game space'

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A final point is that it gives scope to create games where the key is collaboration to achieve a greater viability rather than simply beating other people. In a collaborative learning game 'winning' is coming up together with greater understanding of the challenge and what to do about it than was present at the start of the game.

Conclusion

The world system model described here can be applied as an arena for interpersonal collaboration. For example, any scenarios generated within the 12-node system will involve applying knowledge from several traditional disciplines. The framing brings together disciplines such as sociology, economics, engineering and ecology in an integral way. The diagram provides a transdisciplinary framework which makes it easier for diverse members of a group to exchange their specialized knowledge within a common framework and thus enable synthesis. It encourages holistic approaches to complex issues rather than a reductionist analytical approach which inhibits transdisciplinary work. This aspect creates a greater chance that a group of people coming together around the model with a shared issue will develop a collective intelligence about that issue which is more powerful and comprehensive than any individual or any individual discipline could achieve.

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