

■ *Research Paper*

Managing Complex Issues through Evolutionary Learning Laboratories

Ockie J. H. Bosch^{1*}, Nam C. Nguyen¹, Takashi Maeno²
and Toshiyuki Yasui²

¹Systems Design and Complexity Management Alliance, Business School, The University of Adelaide, Adelaide, SA Australia

²Graduate School of Systems Design and Management, Keio University, Hiyoshi, Japan

Policy makers, managers and leaders in organizations, governments and business institutions are under increasing pressure to make the right management decisions in the face of a continually changing political and socio-economic landscape. To make matters more challenging, the complex environmental, socio-economic, business-financial issues that decision makers need to deal with tend to transcend the jurisdictions and capacities of any single organization. There is a multitude of difficult, long-term global challenges ahead, almost all of which are coupled with the most pressing concerns of different countries at national and local levels. Despite many efforts to deal with these complex issues facing our society, the solutions so far have seldom been long lasting, because 'treating the symptoms' and 'quick fixes', using traditional linear thinking, are the easiest way out, but do not deliver the solutions. This paper describes the processes for unravelling complexity through participatory systems analysis and the interpretation of systems structures to identify leverage points for systemic interventions. It further demonstrates the promotion of effective change and the enhancement of cross-sectoral communication and collaborative learning. This learning focuses on finding solutions to complex issues by applying an iterative, systems-based approach, both locally—Evolutionary Learning Laboratory (ELLab)—and globally—Global Evolutionary Learning Laboratory (GELL). A generic framework and processes for implementing and institutionalizing ELLabs are described, and how these become part of the GELL for managing complex issues is explained. Four case studies are used to demonstrate diverse examples of the application and implementation of the ELLab approach. Copyright © 2013 John Wiley & Sons, Ltd.

Keywords management; policy making; investment decisions; complexity; systems thinking; participatory systems analysis; Global Evolutionary Learning Laboratory (GELL)

*Correspondence to: Ockie J. H. Bosch, Systems Design and Complexity Management Alliance, Business School, The University of Adelaide, Adelaide, SA 5005 Australia.
Email: ockie.bosch@adelaide.edu.au

INTRODUCTION

Complexity characterizes the world and all human endeavours today—in business, government, social, natural, scientific and political spheres. Local and global problems and challenges facing our world today are highly complex in nature, involving decision makers, scientists, NGOs and various other stakeholders. These problems and challenges cannot be addressed and solved in isolation and with the single dimensional mindsets and tools of the past. Collaborative, systemic and integrated approaches are essential to deliver the sustainable outcomes desired. It has become crucially important for decision makers and managers involved in the management of any system to be equipped with the necessary capabilities and skills to make good policy and management decisions.

In recent years, there has been a growing recognition of human capacity development as a key lever for sustainable economic, social and ecological development. However, recent literature on the success of external actors and agencies in implementing effective change in developing countries or regions shows poor outcomes across the board (Umaña 2002; Land *et al.*, 2009; Thomas and Amadei 2010). One of the key barriers to progress is the lack of common understanding and shared vision of how to address the complex issues facing our world. The lack of cross-functional collaboration leads to fragmented decision-making and uncoordinated actions. This is further exacerbated by cross-purpose negotiations, the wasting of public and natural resources, and a loss of confidence in leadership and governance. Over time, these all escalate into a vicious cycle of mediocre performance and poor outcomes for all concerned. A further important contributor to poor outcomes is the fact that many of the ways in which problems are being addressed are simply ‘quick fixes’ or ‘treating the symptoms’. The establishment of a systems-based Learning Laboratory (LLab) has proven to be an innovative and effective approach (Bosch and Nguyen 2011; Nguyen *et al.*, 2011) for dealing with highly complex and multi-dimensional problems and ensuring that solutions will be found at the level of the root causes.

In addition, we manage the systems we are part of in a highly compartmentalized structure—organizations, divisions within organizations, business institutions, government departments, university schools, disciplines and so on. These structures help our society to operate in an orderly way. However, without an understanding that all these different sectors in life are highly interconnected and that there is a strong need for interdisciplinary, cross-sectoral communication and collaboration, solutions that effectively address the multi-dimensional and multidisciplinary nature of complexity will remain elusive.

This paper presents the methodology and application of a ‘new way of thinking’ and radical approach to enhancing cross-sectoral and organizational communication and collaboration, to deal with increasing complexity and to promote effective change at local and global levels.

SYSTEMS THINKING

Although systems thinking is an ‘old’ concept (Midgley 2003), it is increasingly being regarded as a new way of thinking to understand and manage complex problems at both local and global levels (Bosch *et al.*, 2007b; Cabrera *et al.*, 2008). Maani and Cavana (2007) used the analogy of an iceberg to illustrate the conceptual model known as the Four Levels of Thinking (Figure 1) as a framework for systemic interventions.

In this model, events or symptoms (those issues that are easily identifiable) represent only the visible part of the iceberg above the waterline. Most decisions and interventions currently take place at this level, because quick fixes (treating the symptoms) appear to be the easiest way out, although they do not provide long-lasting solutions. However, at the deeper (fourth) level of thinking that hardly ever comes to the surface are the ‘mental models of individuals and organisations that influence why things work the way they do. Mental models reflect the beliefs, values and assumptions that we personally hold, and they underlie our reasons for doing things the way we do’ (Maani and Cavana 2007, p.15).

Moving to the third level of thinking is a critical step towards understanding how these mental

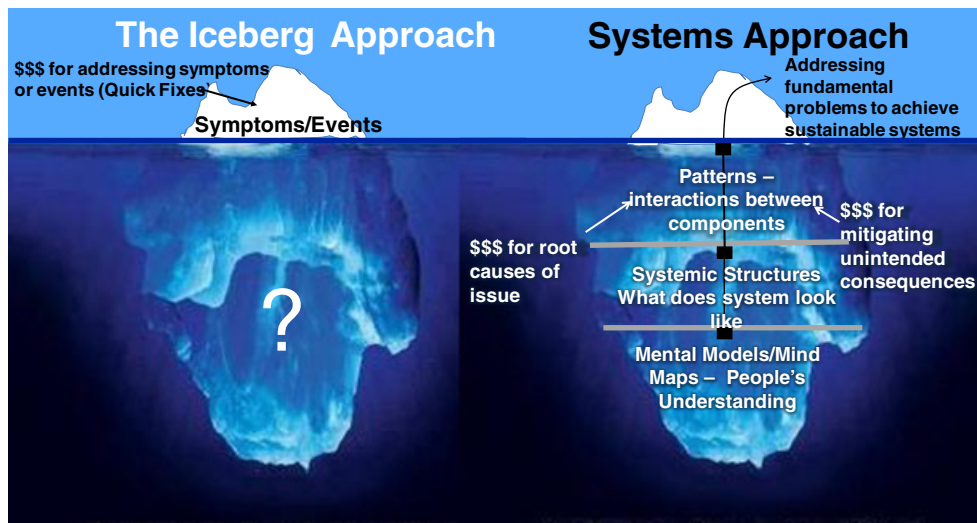


Figure 1 The iceberg approach versus a systems approach

models can be integrated in a systems structure that reveals how the different components are interconnected and affect one another. Thus, systemic structures unravel the intricate lace of relationships in complex systems.

The second level of thinking is to explore and identify the patterns that become apparent when a larger set of events (or data points) become linked to create a 'history' of past behaviors or outcomes and to quantify or qualify the relationships between the components of the system as a whole.

The systems thinking paradigm and methodology embrace these four levels of thinking by moving decision makers and stakeholders from the event level to deeper levels of thinking and providing a systemic framework to deal with complex problems (Maani and Cavana 2007).

The application of systems thinking has grown extensively and encompasses work in many diverse fields and disciplines such as, to mention but a few, management (Jackson, 2003), business (Sterman 2000; Walker *et al.*, 2009), decision making and consensus building (Maani and Maharraj 2004), human resource management (Quatro *et al.*, 2007), organizational learning (Galanakis 2006), health (Newell 2003; Lee 2009), commodity systems (Sawin *et al.*, 2003), agricultural production systems (Wilson 2004), natural resource management (Allison and Hobbs 2006), environmental conflict management (Elias 2008), education (Hung

2008), social theory and management (Mingers 2006), and food security and population policy (Keegan and Nguyen 2011). This paper is the first to demonstrate how a comprehensive systems thinking approach, embedded in a cyclic Evolutionary Learning Laboratory (ELLab) framework, can be used to deal effectively with complex issues in a variety of contexts.

ESTABLISHING A SYSTEMS-BASED EVOLUTIONARY LEARNING LABORATORY

The LLab is a process, as well as a setting, in which a diverse group of participants engage in a cyclical process of thinking, planning, action and reflection for collective learning towards a common good. It is an environment where policy makers, managers, local facilitators and researchers collaborate and learn together to understand and address complex problems of common interest in a systemic way (Maani and Cavana 2007). The ultimate goal is to achieve coherent actions directed towards sustainable outcomes.

The ELLab is a seven-step iterative process (Figure 2) of group thinking and acting in which the participants engage in well-defined activities and thus learn together in an 'experimenting lab' environment about how best to deal with the complex multi-dimensional and multi-stakeholder

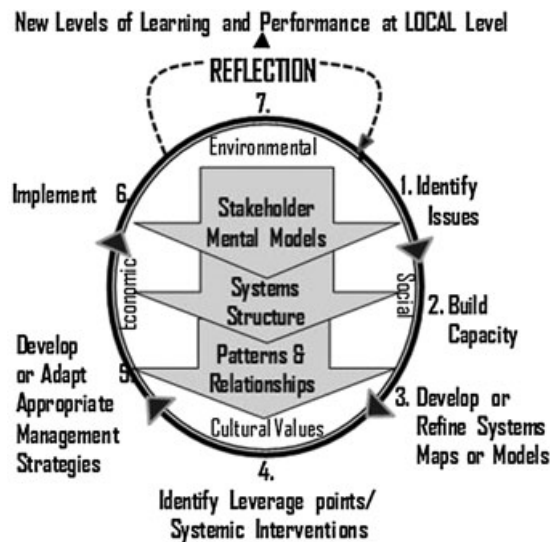


Figure 2 Evolutionary Learning Laboratory for managing complex issues

problems they are facing. Although it builds on evolutionary design principles as described in the work of Banathy (1996) and the concept of evolutionary leadership developed by Laszlo (2001), the process of establishing an ELLab (Figure 2) could be regarded as a unique 'methodology' to collaboratively integrate and use existing and future knowledge to help manage complex issues. It starts at the 'fourth level of thinking' with an issues workshop (step 1) and a series of forums with specialist groups to gather the mental models of all stakeholders involved in the issue under consideration, their perceptions of how the system works, what they regard as barriers to success and drivers of the system, and possible strategies (solutions) to overcome these problems.

This is followed by implementing the 'third level of thinking' through follow-up capacity-building (step 2) sessions during which the participants (all stakeholders) learn how to integrate the various mental models into a systems structure (step 3). The Vensim software program (Systems 2011) is a valuable tool for the development of a systems model (causal loop diagram) of the issue under consideration. This learning step is of particular importance in order for all involved to take 'ownership' of the systems model.

Once completed, the participants move to the 'second level of thinking' by interpreting and exploring

the model for patterns, how different components of the model are interconnected and what feedback loops, reinforcing loops and balancing loops exist. This step aims to assist relevant stakeholders to develop an understanding of their interdependencies and the role and responsibility of each stakeholder group in the entire system. The main barriers and drivers of the system are discussed in more detail, which provides the stakeholders with an opportunity to develop a deeper understanding of the implications of coordinated actions, strategies and policies. Overall, this process provides all stakeholders with a better understanding of each other's mental models and the development of a shared understanding of the issue(s) under consideration.

The interpretation leads to the identification of leverage points for systemic intervention (step 4). Leverage points are places within a complex system (e.g. an economy, a living body, a city and an ecosystem) 'where a small shift in one thing can produce big changes in everything ... leverage points are points of power' (Meadows 1999, p.1). Senge (2006, p.64) also refers to leverage points as the 'right places in a system where small, well-focused actions can sometimes produce significant, enduring improvements'. Identification of leverage points greatly assists the devising of systemic interventions (finding systems-based solutions) that will contribute to the achievement of goals or solving problems in the system under consideration.

The outcomes are used to develop a refined systems model, which forms at the same time an integrated master plan (step 5) with systemically defined goals and strategies (systemic interventions). In order to operationalize the master plan, Bayesian belief network (BBN) modelling (Cain *et al.*, 1999; Smith *et al.*, 2007) is used to determine the requirements for implementation of the management strategies; the factors that could affect the expected outcomes; and the order in which activities should be carried out to ensure cost effectiveness and to maximize impact.

The process of developing good policies and investment decisions is based on the best knowledge (scientific data and information, experiential knowledge, expert opinions) that is available at any point in time. The systems model can be used to test the possible outcomes of different systemic

interventions by observing what will happen to the system as a whole when a particular strategy or combination of strategies is implemented, that is, before any time or money is invested in actual implementation.

Of particular value is the ability through BBN modelling to also 'back-cast'. That is, the goal is set at a 100% probability that it will be achieved and the model back-casts and points out which of the components, actions or conditions have the most influence on the achievement of the goal. This is a powerful way of determining where to invest time and resources, instead of having only a list of recommendations, without an understanding of how they are interconnected, which ones are the most important to invest in and in what order the strategies should be implemented to ensure an efficient and cost-effective plan of action.

Once the systemic interventions have been identified and an operational plan has been developed, the next step for the people who are responsible for the different areas of management is to implement the strategies and/or policies (step 6) that will create the biggest impact. Targets are determined, and monitoring programs are implemented to measure and/or observe the outcomes of the strategies and policies. In many cases, it only requires an adjustment of existing monitoring programs to comply with the targets set within the ELLab process (e.g. to include factors to be measured that were used in the construction of the Bayesian management model).

Because no systems model can ever be completely 'correct' in a complex and uncertain world and unintended consequences always occur, the only way to manage complexity is by reflecting (step 7) at regular intervals on the outcomes of the actions and decisions that have been taken to determine how successful or unsuccessful the interventions are and to identify unintended consequences and new barriers that were previously unforeseen.

The iterative process serves as a valuable informal co-learning experience and leads to new levels of capability and performance. Working in this way as a coalition is the most effective way to deal with complex issues; because the methodologies and processes acknowledge that complex problems are multi-dimensional and have to involve all stakeholders, they require cross-sectoral communication

and collaborative approaches to resolve, and deal with many uncertainties that need adaptive management approaches as more knowledge becomes available through the iterative process of learning by doing.

USING ELLABS TO DEAL WITH COMPLEX ISSUES IN A VARIETY OF CONTEXTS

As mentioned earlier, the ELLab approach is generic and can be used in dealing with any complex issue, regardless of its context (e.g. organizational, natural or social systems) or discipline area under consideration (e.g. business, health, engineering, education and marketing). In the following sections, four case studies are used to demonstrate four diverse examples of the application and implementation of the ELLab approach.

Sustainable Development of a UNESCO Biosphere Reserve in Vietnam

Biosphere reserves (BRs) are sites recognized under the UNESCO Man and the Biosphere (MAB) program to demonstrate innovative state-of-the-art approaches to conservation and sustainable development. A comprehensive description of the origin and the evolution of the BR concept is presented in a paper (Ishwaran *et al.*, 2008). There are currently 580 BRs in 114 countries (UNESCO 2012). UNESCO has recommended the launch of pilot projects to use BRs as learning laboratories to address the gap between BR knowledge systems (scientific, experiential and indigenous) and the imperative for wider sustainable development. In this regard, the first pilot project, the Cat Ba Biosphere Reserve (CBBR) sustainability project in Haiphong City, Vietnam, has been initiated (Nguyen *et al.*, 2011). The project focuses on the interconnectedness of environment, tourism, livelihood of people and economic benefits, and the adoption of policies and processes by government and management bodies to ensure that long-term sustainable management will become institutionalized and ongoing.

Identify Issues

Two workshops were conducted in March and October 2007 (Bosch *et al.*, 2007a) with a range of stakeholders to gather their mental models on the key issues and challenges that Cat Ba Island is facing. These include waste treatment, pollution, the high number of floating farms, overuse of underground water, strong growth in tourism, lack of fresh water and electricity (especially in the summer—tourist season), lack of skilled labour for the tourism industry, uncontrolled tourism development, insufficient infrastructure, lack of access to suitable markets for locally produced products, encroachment on conservation areas, lack of integrated planning, lack of capacity, environmental degradation and poverty.

Build Capacity

A 2-month systems thinking and associated capacity-building program was subsequently conducted in Australia (October and November 2008) for a group of 10 policy makers, managers and technical officers from different levels of government, across sections of agencies and an NGO, engaged in different capacities in the management of the CBBR. The process and outcomes of this capacity-building program have been reported in a recent paper (Nguyen *et al.*, 2012).

Develop a Systems Model

During the capacity-building program, participants worked with the research team to integrate the various issues identified in the issue workshops into a preliminary systems model. Subsequently, the model (Figure 3) was refined and validated by various relevant stakeholders (managers and rangers of Cat Ba National Park, hotel owners, farmers, local people and officials from different government departments) in a series of workshops, focus group discussions and in-depth interviews conducted in Haiphong City and on Cat Ba Island at the end of 2008 and early 2009. This involvement in the evaluation of the model was critical because it led to taking ownership of the model and enhanced the ability of stakeholders to

understand and carry out future intervention strategies and actions aimed at improving the system for sustainable outcomes.

Figure 3 illustrates the identified interrelationships and interdependencies amongst the key components of the system. The systems model represents a 'big picture' of the CBBR system and provides a useful platform for learning, collaboration and decision making for relevant stakeholders including policy makers, researchers, managers, practitioners and local people.

Identify Leverage Points and Systemic Interventions

A follow-up workshop was conducted in Haiphong City in May 2009 with the main objective to identify key leverage points and areas for systemic interventions for sustainability—on the basis of the systems model of the CBBR and its associated systems archetypes. Systems archetypes 'reveal an incredibly elegant simplicity underlying the complexity of management issues. . . [they allow us] to see more places where there is leverage in facing difficult challenges, and to explain these opportunities to others' (Senge 2006, p. 93). Four systems archetypes were identified in the systems model of the CBBR—'limits to growth', 'fixes that fail', 'tragedy of the commons' and 'shifting the burden'. These archetypes are discussed in detail by Nguyen and Bosch (2012) and not repeated in this paper.

The leverage areas require systemic interventions that are deemed critical for the long-term sustainability of the CBBR. Those identified included cross-sectoral collaboration; development and implementation of government plans; capacity building for decision makers, managers and local people; waste management and treatment; people's awareness; conservation of endangered species; investment for agriculture; improving the livelihood of commoners; and tourism development. These leverage areas form the basis for integrated projects and policies covering multiple aspects of the sustainability of the CBBR, including social, economic, cultural and environmental well-being.

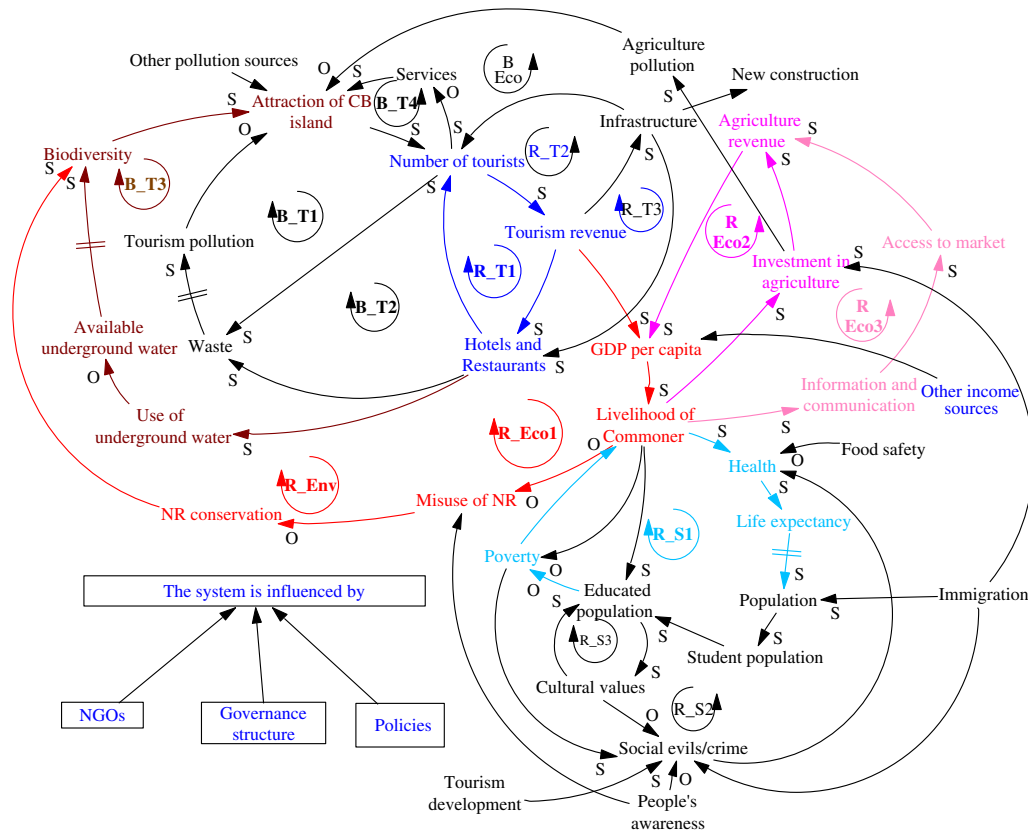


Figure 3 Systems model of CBBR—a platform for collaboration (adapted from Nguyen et al., 2011). Legend: S, same direction; O, opposite direction; R, reinforcing; B, balancing; T, tourism; Eco, economic; Env, environment; S, social. 1, 2, 3 refer to loop number; for example, R_T1, reinforcing loop no. 1 of tourism

Develop Action Plans

A series of Bayesian models were constructed to develop action plans for the identified leverage areas and systemic interventions. An example of these models is illustrated in Figure 4.

The Bayesian model developed in this study (Phan 2011) is designed as a decision support tool to assist the management board of the CBBR and Cat Ba National Park in developing feasible management and action plans for the conservation and protection of the population of an endangered species (serow—mountain goat) in the CBBR.

Short-term and long-term measures for this endangered species are needed. In the short term, stronger engagement of local people, especially the potential poachers, to participate in serow protection is necessary. Intensifying patrol activities in prioritized conservation areas is needed

to avoid any further loss of individual animals. Simultaneously, more stringent law enforcement by authorities and adopting more severe punishment measures for illegal hunting are required.

In the long term, providing opportunities to improve the financial position of the poor through technical support and education is one of the most important and sustainable solutions to improve the livelihoods of people on the island. This would avoid the increasing impact of local people on the resources of the National Park. Raising the conservation awareness of local residents and improving the knowledge and management capacity on biodiversity conservation and conservation planning of managers of the Cat Ba National Park are vital to ensure an effective conservation outcome in the CBBR (Phan 2011).

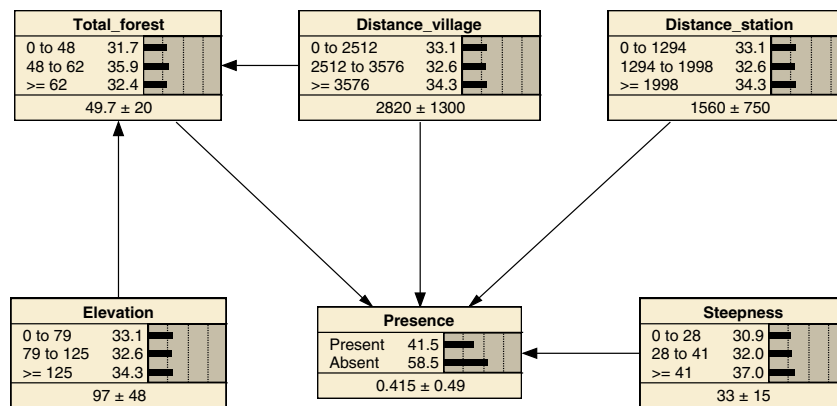


Figure 4 Bayesian model of serow occurrence in the CBBR (adapted from Phan, 2011)

Implementation

A series of strategies are currently being implemented to improve the livelihood of the commoner. A comprehensive model has also been developed for sustainable tourism development as a mechanism for improving the livelihoods of people on the island (Mai 2012), whereas models for improving waste management and agricultural market access are currently being completed. Several small projects and actions have also been undertaken to address the various leverage points and systemic intervention strategies that had been identified from the systems model and its associated systems archetypes. These include building the capacity of the rangers to systemically manage the National Park; conducting a social welfare study relating to community development in the CBBR; producing an annual Cat Ba Ecosystem Health Report Card; establishing community partnerships in natural resource management and environmental protection; and relocating the floating farms away from main tourism areas and out of the national marine protected areas.

Reflection

The early and consistent involvement of key decision makers and stakeholders (nearly 200 participants to date) has been of paramount importance for the successful formation and implementation of an ELLab for sustainability in the CBBR. This involvement will be of significant importance for the seamless continuity and sustainability of the project.

Frequent reflection on the successes and failures of implemented strategies (systemic interventions) has led to new knowledge and ideas. For example, to enhance awareness of sustainable practices and increasing employment of locals, a CBBR brand system has been introduced that is awarded to products (e.g. fish sauce and honey) and businesses (e.g. tourist boat services, recreation parks, hotels, guest houses and restaurants) that complies with a set of relevant criteria such as business registration, water saving mechanisms, employing local people, fire safety standards, food safety and hygiene standards. The collaborative learning process has also led to a strong realization that the CBBR management regulations need revision, especially to improve integrated planning and actions across different sectors of society.

Policy Design for Child Safety in Japan

In OECD member countries, more than 125 300 children died from injuries from 1991 to 1995, which amounts to 39% of all deaths. Japan was ranked as a medium-risk performer in deaths by drowning, fire, falls and intentional harm, whereas deaths due to car accidents were significantly lower than in other countries (UNICEF, 2001). Japanese society often regards parents as the only people responsible for child safety. Japanese parents tend to feel isolated and frustrated, because there is a clear lack of a coordinated approach with other stakeholders in the society to help prevent injury to their children (Kakefuda

et al., 2008). The complexity of this issue warranted a participatory systems analysis approach to create possible solutions by embedding the systems model in an ELLab context in order to ‘experiment’ with potential solutions that could lead to better policies for a safe and secure society.

Identify the Issues

The mental models of a wide variety of relevant stakeholders about the issue were obtained from a focus group meeting (conducted in September 2011) to identify and visualize all factors related to child injuries.

Build Capacity and Develop a Causal Loop Model

A workshop was held in September 2011 during which various stakeholders collaboratively constructed a causal loop diagram to identify the components of the system and to explore the interactions and relationships between them. The facilitator of the group had undergone intensive training in systems methodologies, which made it possible to structure the mental models of the various participants into a model.

Identify Leverage Points and Systemic Interventions

Special attention was given to the identification of reinforcing and balancing loops in order to assist in the identification of possible leverage points for systemic interventions. This was carried out through visual observation and discussions between participants on the potential degree of change that could be caused by changes to particular components of the system. Seven systemic intervention points were identified (in bold, Figure 5): safer product designs, caring volunteers to support frustrated parents, closer involvement of social workers, more integrated approach by government, more paediatricians, shortening of the time between an accident and hospitalization, and better care of students in schools.

Develop Action Plans

The participating stakeholders used the seven systemic intervention points to structure a BBN model for designing policies on child safety (Figure 6). The model was populated by various stakeholders who jointly used their experiential knowledge to decide on the probabilities of how the parent nodes would affect the child nodes. For example, what are the probabilities that more scholarships and better insurance policies will

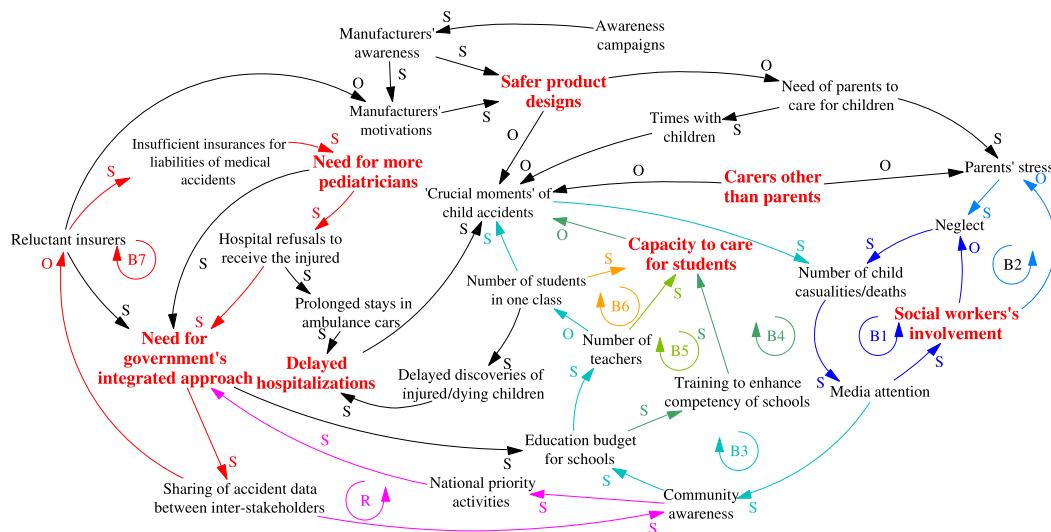
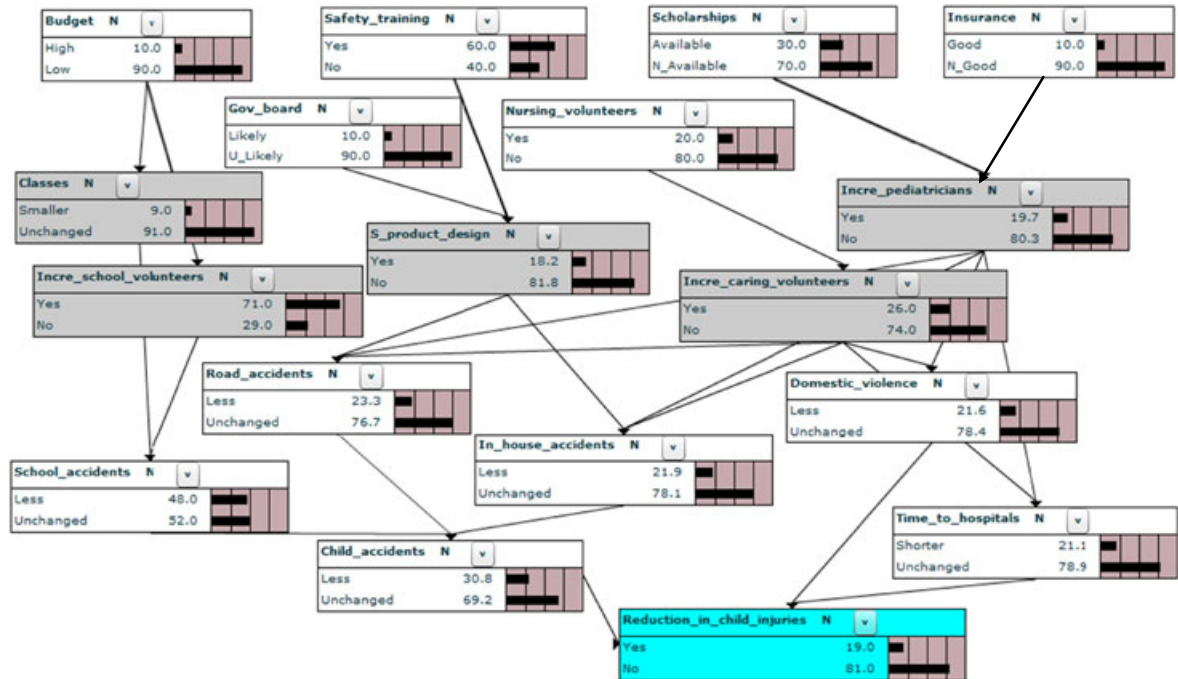


Figure 5 Causal loop diagram and identified systemic interventions points for child safety in Japan

(a)



(b)

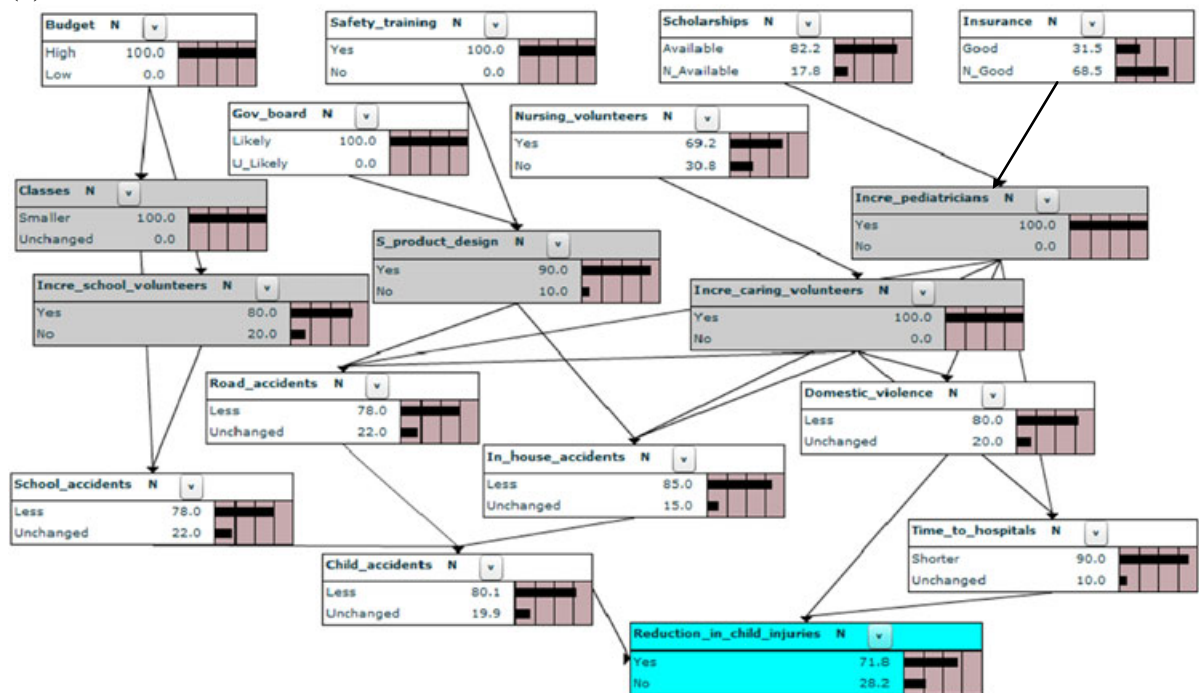


Figure 6 Populated Bayesian model for child safety: (a) current conditions and (b) indicating the main leverage points and systemic interventions that were identified

lead to an increase in the number of paediatricians? How would designer training and a government that could test the designs change the probability that the design of products will be safe? and What is the probability that there will be less school accidents if there are more school volunteers and smaller classes?

Through this co-designing process, the stakeholders recognized that the Bayesian model, populated with information about the current conditions, indicated that there is only a 19.0% probability that the rate of child injuries will be reduced (Figure 6(a)).

A sensitivity analysis of the model indicated that the most effective parameter to reduce child injuries was to increase the number of volunteer nursing councillors (Figure 6(b)). The model indicated that if the number of volunteer nursing councillors is set at 100%, the probability that less child injuries will occur will rise to 46.7%. However, also providing designer training in child safety, establishing a government board for product evaluation, reducing the size of classes in schools and having sufficient numbers of paediatricians will increase the probability to have less child injuries to about 72%. Therefore, although a policy to increase the number of volunteer nursing councillors would make a big difference, these additional four systemic interventions were also identified as important to significantly reduce child injuries (step 5).

Implementation

A change in the policy to increase voluntary nursing staff and implementation of the additional systemic interventions have been proposed in order to experiment how these interventions will affect child injuries.

Reflection

The models have been constructed with the best experiential knowledge available at the time. These models are therefore embedded in the cyclical process of 'experimenting' and reflecting through which new knowledge will be created. Strategies will be refined in a co-learning

environment to find the best solutions for this complex problem over time—forming the ELLab.

Enhancing the Reputation of a University School in Japan

The Graduate School of Systems Design and Management (SDM) at Keio University in Japan was established in 2008. This school is rapidly becoming a focus point in the Asia-Pacific region for its mission to educate students who can solve complex and large-scale problems in any system ranging from social (human dimensions) to highly technological issues. The school is building its foundation on systems and design thinking and has a strong focus on industry and community needs, while taking into account that all problems are embedded in a complex web in which environment, security and safety, health and welfare, economics, politics and culture are all highly interconnected. What makes the school particularly unusual is the fact that it attracts students for masters and PhD programs from all different disciplinary backgrounds (Figure 7), which creates a collaborative learning environment for the evolution of creative and innovative thinking and systems design.

In April 2011, SDM decided to revisit its initial vision and strategies in order to develop a 'clearer and more committed operation' and to be recognized as a world-class institution in the area of systems design. Because of the complexity of this task and the intention of the school to find long-lasting solutions, rather than quick fixes, SDM decided, as part of this process, to establish the school as an ELLab.

Identify the Issues and Build Capacity

The first step was to hold a workshop represented by a number of students and staff members who were all trained (step 2) in the development and interpretation of systems models. The participants' mental models on how they believe the school can improve its reputation, the drivers and barriers in achieving this and possible solutions to overcome the barriers were collected.

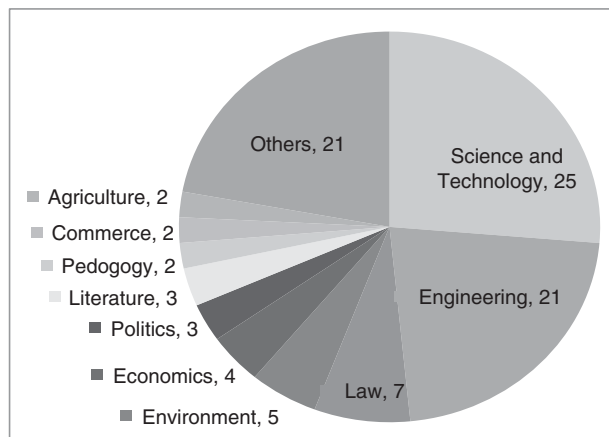


Figure 7 Diverse backgrounds of students in the 2012 postgraduate class

Develop and Interpret a Bayesian Belief Network Model

In this particular case, the mental models were integrated by directly structuring them into a conceptual inference diagram, which formed the basis for a BBN model (Figure 8).

The probability tables were populated with the experiential knowledge (mental models) of the participants to form a first draft model that described the main components of the system and how they are related to each other (step 3). Testing of different scenarios by changing different components of the model and combinations of components facilitated an evaluation of how well the model reflects the real situation. With this information, the probability tables were revisited and refined until the model provided a realistic description of the current school and the system in which it operates.

Identifying Leverage Points and Systemic Intervention Strategies

Patterns and relationships were explored by changing each of the components in the 'what can we do' or 'action' nodes of the model individually to observe how such a change affects the end goal of SDM to be recognized as a world-renowned school with a reputation of excellence.

Appointing or consulting a competitive intelligence professional that can provide appropriate

intelligence for different audiences (e.g. industry and potential students) for more effective promotion and marketing of SDM [the probability for this to occur changed from 54% to 90%—comparing Figure 8(a, b)] will have the largest single effect on achieving the goal to become a world-class school, increasing the probability from 64% to 72%. Other outcomes that will improve the probabilities for achieving the end goal include an increase in the number of applications (from 58% to 86%) and the probability that more high-quality professors will be attracted to SDM (from 57% to 85%). A further improvement of the relationships that SDM already has with industry will have the second largest effect on the goal. This will lead to the probability to increase the budget of SDM from 56% to 80%; for students to have access to better research facilities from 63% to 90%; and the ability to fund language training from 52% to 72%.

Implementing both the aforementioned actions will lead to an increase in the probability to achieve the end goal from 64% to 76%. This probability can further be increased to 80% by reviewing the criteria for entry to SDM. More stringent criteria will lead to a higher probability of high-quality students; and if they have good communication skills (through language training) and work under the supervision of high-quality professors (who are attracted by good promotion), the probability for high-quality research will increase from the current 61% to almost 80%.

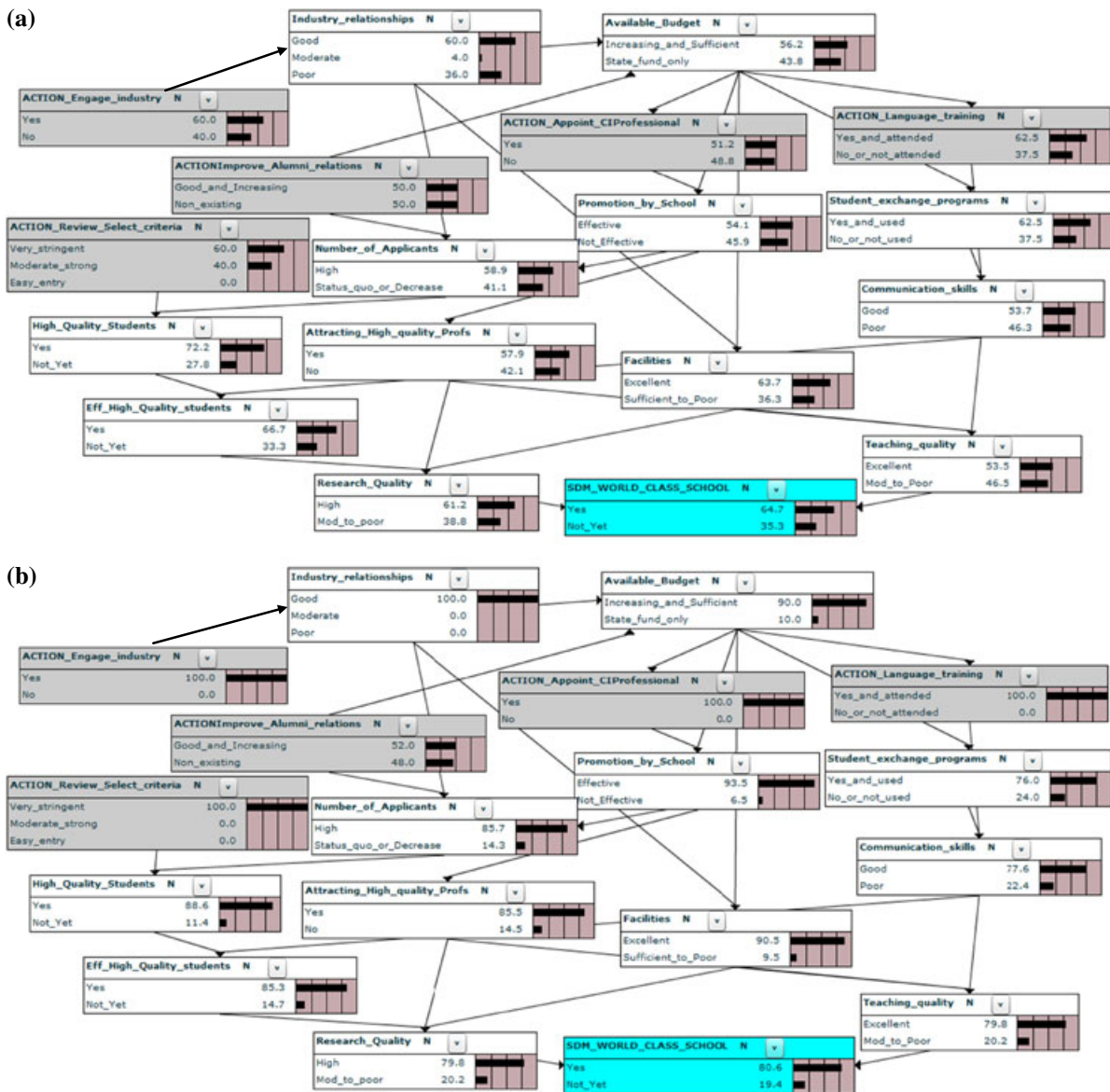


Figure 8 First draft BBN model to enhance the reputation of the school: current situation (a) and with systemic interventions implemented (b)

Implementation

In summary, to achieve SDM’s goal of being recognized as a world-class institution, investment should first be in appointing or consulting a competitive intelligence professional and in further enhancing its relationships with industry. A combination of these two actions will have the biggest effect on the end goal. Other actions that could be implemented, but would not significantly

contribute to achieving the end goal, include the provision of language training and more stringent selection criteria to ensure high-quality students with good communication skills.

The school is consulting an expert in the area of competitive intelligence (one of its staff members) to develop effective marketing and promotion material and mechanisms for different types of audiences (e.g. large companies, potential students

and government departments). Stronger collaboration with industry is being established through the selection of real issues in different companies and government agencies for student assignments and masters projects (e.g. Toshiba, NEC and Yokohama City).

Reflection

The effects of changes in those parameters of the model that were identified during model development as being affected by the actions undertaken are being monitored (e.g. increase in the school budget, language competency, number of student enrolments and availability of quality research facilities in industry). The outcomes of these will be used to refine the first draft model—starting the cyclic process of experimenting and adapting of the SDM ELLab.

Managing Tree Density in the Rangelands of Northern Queensland, Australia

Much of Australia's grazing land is composed of woodland. Trees and native pastures coexist in these ecosystems, where they compete for water, nutrients and sunlight. However, there is also a mutually beneficial relationship between trees and pastures, provided that the balance is right. When a favourable tree–grass balance exists, trees provide shade and shelter for livestock and support biodiversity. They also carry out key ecosystem functions, such as water and soil nutrient cycling, and contribute to healthy land condition by preventing erosion and salinity, storing carbon and enhancing soil condition (Liedloff and Smith 2010).

There is an increasing recognition of the role that trees play in grazing systems, which has led to a demand for sustainable woodland management. Of particular importance is the management of tree cover thickening in the tropical savannas, which has the potential to change catchment hydrology (Krull *et al.*, 2007), carbon stocks (Burrows *et al.*, 2002; Henry *et al.*, 2002), pasture biomass available for grazing animals (van Langevelde *et al.*, 2003) and wildlife habitat (Tassicker *et al.*, 2006). Tree thickening is therefore an

important issue to many stakeholders, including pastoralists, conservationists, land managers and those interested in carbon markets, each with a wide range of opinions and vested interests in the process (Bosch *et al.*, 2007b).

The demand for better management of the complex interactions between different factors and components of the tree thickening system has led to the establishment of an ELLab for sustainable woodland management.

Identify Issues

Several workshops were held during 2005 in different localities in the rangelands of Northern Queensland. Graziers, researchers and extension officers discussed the tree thickening problem and identified the factors that they believed would influence tree density. Possible management actions and non-manageable factors that might influence density were also identified and discussed.

Build Capacity and Develop a Model

The knowledge of the workshop participants was captured by mapping out an influence diagram. The process allowed for the integration of the different mental models of the stakeholders (varying perspectives and divergent views). While divergent views occur, the appreciation of each other's views gained through 'mapping the system' helped stakeholders to develop a common understanding of the management system.

The influence diagram (Figure 9) provided a structure through which stakeholders could express and discuss their understanding of the cause and effect relationships between management actions, controlling factors and resource management outcomes or goals. The diagram also assisted the stakeholders in identifying how their knowledge contributed to a better understanding of the overall management system and to appreciate how other stakeholders understand the links between management actions and outcomes (providing a mechanism for externalizing and internalizing knowledge). This co-learning process (capacity building) consists of individual stakeholders who are socializing and externalizing

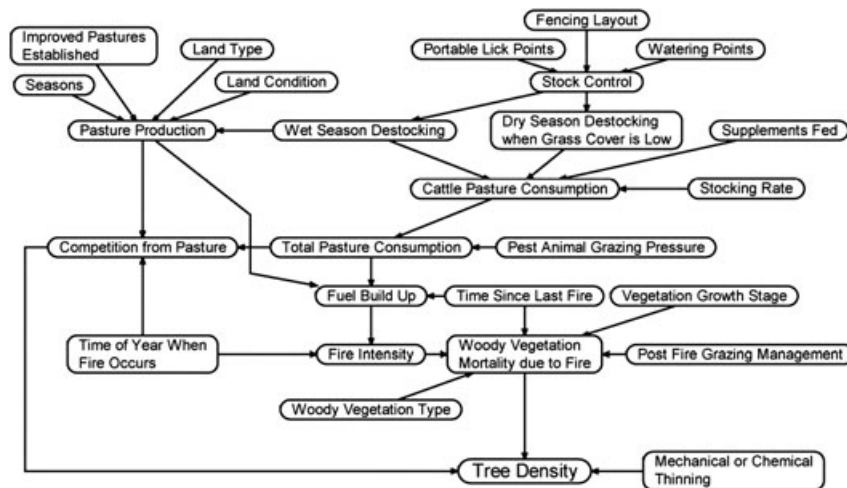


Figure 9 Influence diagram of issues related to managing tree density (adapted from Bosch *et al.*, 2007b)

their knowledge within a group, combining this knowledge, and learning from each other (internalization) (Nonaka and Konno 1998).

The influence diagram was used as a framework for the development of a BBN model (Figure 10) through which it was possible to integrate experiential knowledge, scientific data and models to populate the BBN model. This processes ensured that the knowledge created by scientists became integrated with the understanding of systems by land managers, conservationists and other stakeholders.

Figure 10 shows a completed BBN systems model for tree density management. Each node has two or more states, and arrows represent the causal relationships between nodes. Conditional probability tables (CPTs) specify the relationships between the nodes. Bosch *et al.* (2007b, Table 1) described the CPT in an example of how fuel build-up and fire season influence fire intensity. The first row represents the scenario where fuel build up is high (>1800 kg/ha) and the fire season (time of fire) is 'late_dry' (October/November). 'Under this scenario there is a 100% chance that fire intensity will be hot. By completing the probability table for each node in the BBN, available data, information and experiential knowledge are integrated in a systematic way. The result is a knowledge base and a dynamic systems model that can

assist stakeholders (particularly managers) in decision-making through analysing different scenarios' (Bosch *et al.*, 2007b, p. 220).

Identify Leverage Points and Systemic Interventions

An evaluation of the model and identification of leverage points and systemic interventions that will affect the goal (avoid thickening of tree density) was done by testing model behavior with stakeholders through applying different management scenarios and predicting the possible outcomes. Back-casting was also used to identify which actions and factors would have the largest effect on the goal, providing or confirming the systemic interventions identified during scenario analysis.

The incidence of fire and the factors that determine the nature of fires were identified as the most important leverage point for controlling thickening of trees. This conclusion was verified by scientific data and models (Liedloff and Smith 2010) and experiential knowledge of land managers. It was mentioned that where fire has been a regular feature within the landscape, the removal of fire will often lead to woodland thickening. Grazed woodland ecosystems evolved with fire, which suppresses tree thickening. Without a disturbance such as fire, many land types will have a higher tree density.

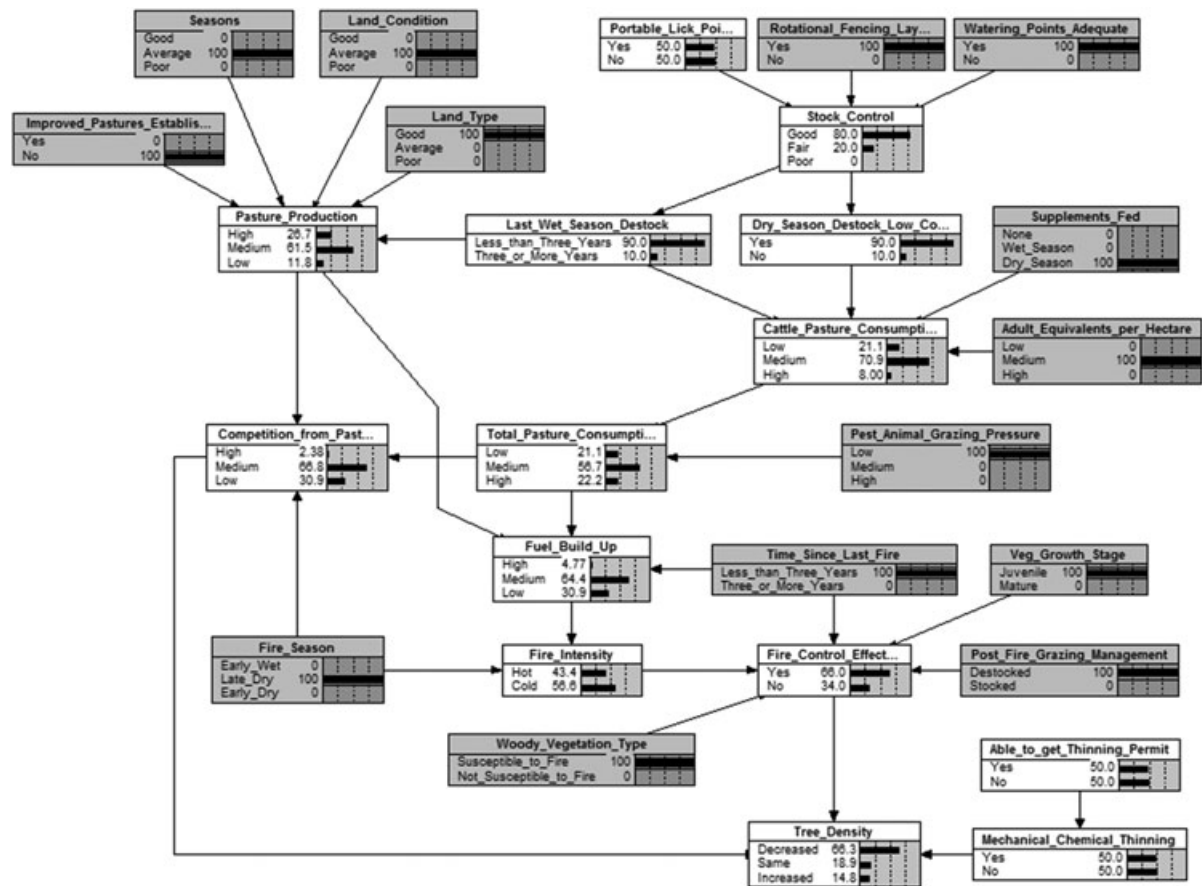


Figure 10 BBN model for tree density containing alternative scenario (adapted from Bosch et al., 2007b)

Develop Management Plan and Implementation

From the BBN model, it was clear that the most economic and environmentally sustainable way to control tree cover thickening is with fire, provided conditions such as fuel load are satisfactory. The BBN model served as a tool to identify possible management scenarios before actual implementation.

Reflection

The approach of stakeholder involvement and systems thinking described earlier led to a model that represents the mutual understanding of stakeholders and their current knowledge base for decision making. However, this knowledge base is rarely perfect because natural systems are complex, and their management takes place against a background of continuous and

unpredictable change in environmental, economic and social conditions. Because of this, the uncertainties in achieving the desired resource management outcomes remain high. However, new knowledge about management systems behavior is continuously generated through observation (monitoring) and the evaluation of outcomes of implemented management strategies. Embedding the BBN model in the cyclic process of the ELLab allowed for continuous improvement of the knowledge base, and its usefulness for managing natural resources under uncertain and variable conditions.

Reflecting on management outcomes emphasized the importance of fire as a management tool. It became clear that tree density and structure are constantly changing because of climatic variation and the use of fire. In many regions, a thickening of trees occurred during higher rainfall periods

and thinning during drought. Where fire has been a regular feature within the landscape, its removal often led to the thickening of tree cover. In extensive systems where thickening has occurred, mustering costs have increased by up to 30% and production has suffered as pastures compete for scarce resources. It has become clear that the most economic and environmentally sustainable way to control woody thickening is with fire, provided conditions such as fuel load are satisfactory. This finding during the reflection stage has led to the development of a more detailed model that focuses on the influence of management and non-management drivers on woody vegetation change (Liedloff and Smith 2010).

THE GLOBAL EVOLUTIONARY LEARNING LABORATORY

Once an ELLab has been established in each particular region or country, it will operate as a management tool for the reform and sustainable management of complex issues in their respective

systems. As described in the above case studies, management strategies and policies are implemented and the ELLab runs 'Reflection' meetings (step 7) to discuss the outcomes (successes and failures) and decide how to change the management or how to adapt a policy. These reflection meetings will lead to new levels of learning and enhanced management performance in the different sectors of the system as a whole.

Each individual ELLab will also become part of the Global Evolutionary Learning Laboratory (GELL) (Figure 11) and continually share the lessons it has learned with ELLabs (and other similar innovations) in other parts of the world, through the lenses of different political systems, cultures and so on. GELL is currently being enhanced with advanced e-technologies that will help it to serve as a platform for continuous sharing and co-learning, leading to new levels of learning and performance at regional and global levels. It will also help individual ELLabs to learn more and perform better in their own countries, organizations, businesses and communities.

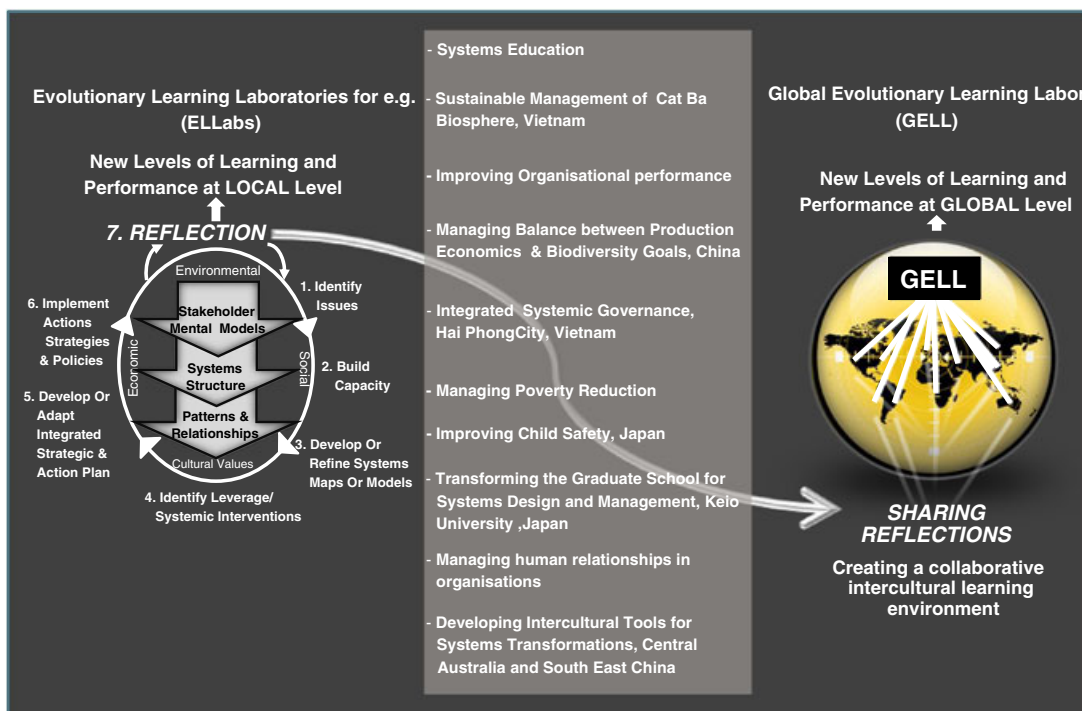


Figure 11 The Global Evolutionary Learning Laboratory (GELL)

CONCLUSION

Globally effective researchers, as well as existing and future leaders and managers, will need to understand complexity and how to deal with it in multi-stakeholder scenarios. Systems thinking is therefore the underlying paradigm and research approach. This paper has described the application of systems thinking in the establishment of ELLabs for managing complex issues through enhancing cross-sectoral communication and collaboration, and promoting effective change. Each ELLab develops uniquely because of the political and cultural systems of each country, organization or business. The GELL can greatly enhance our capacity to address globalized issues and serves as a global knowledge hub.

The establishment of ELLabs and the GELL is an ongoing process. The research so far has achieved various active engagements at specific levels, local and global, including local communities, national park staff, local and national governments, the national MAB committees in different countries and the UNESCO MAB program. UNESCO/MAB has already acknowledged this approach as best practice for potential applications to more than 580 BRs globally (Nguyen *et al.*, 2011).

The research has helped to build the capacity of various people (relevant stakeholders) in different places where ELLabs are being established. The stakeholders are closely involved in all the different steps of the establishment of their respective ELLabs. This close involvement has enabled a shared vision amongst stakeholders and helped them to understand complexity and be able to identify the root causes of problems, rather than merely treating the symptoms. It has also helped them to develop solutions collaboratively over time, experiment with them and be able to adapt when required through knowledge sharing and discussions with others. In addition, the close involvement has enabled the relevant stakeholders to take ownership of the ELLab and to know how to operate it.

Having a 'champion' is another important lesson learned through the research. The authors have been fortunate to work with a champion (a key person in a leading position, who

understands and supports the approach) in every site where an ELLab has been established. This is essential for the successful implementation and operation of the ELLab.

The key challenge in this research is securing funding to address the identified leverage points and systemic interventions. It is common for donors and funding agencies to provide funding for treating the 'symptoms' with quick fixes, in order to see (and show to the world) immediate results from their funding efforts. However, it could take several years for a systems-based approach to achieve long-lasting sustainable outcomes by solving the root causes of problems. Finding the funds for a process with often non-tangible outcomes (as opposed to tangible outcomes such as a bridge, a school or a road) has proved to be a major challenge, especially for developing countries.

A further important challenge is the 'silo' structure of ministries and organizations in every country, which makes 'collaboration' a foreign concept. A paradigm shift is needed to move away from this kind of structure. Further research to institutionalize the ELLab concept, leading to the use of collective intelligence in decision making across sectors and organizations and effective collaborative governance, has become a high priority.

Computer-based modelling systems can be useful tools to explore and make management action decisions that are more systemic than the decisions produced by traditional approaches. Of particular importance is their ability to be used within a participatory process, to enable knowledge capturing, testing and refinement of multi-stakeholders. Used in this way, a computer-based modelling system (such as a BBN) can (i) provide a flexible modelling environment, (ii) allow uncertainty in knowledge to be expressed using probabilistic relationships, (iii) allow biophysical, economic and social variables (either quantitative or qualitative) to be related, (iv) enable a graphical (flow chart) interface that is easily understood and facilitates communication between stakeholders and (v) be easily updated as new knowledge emerges, without the need for specialist computer skills (i.e. nodes added or removed, links changed and probabilities updated).

In summary, a new way of thinking can change the effectiveness of government departments, businesses, organizations and communities in many ways:

- better mutual understanding of the diverse mental models of different stakeholders;
- moving away from traditional linear thinking that leads to quick fixes and treatment of the symptoms, to long-lasting systemic solutions that address the root causes;
- ability to collaboratively identify leverage points and systemic interventions to underpin systems-based master and strategic plans;
- deep understanding of the interconnectedness between possible actions in order to develop efficient and cost-effective management strategies;
- working knowledge of cutting edge systems tools to test the outcomes of strategies, including identification of unintended consequences—before actual implementation;
- ability to use back-casting to identify those factors that will have the most influence on the achievement of goals (knowing where and when to invest in the system); and
- using the ELLab as an ongoing process for continuous co-learning and refinement of management strategies.

REFERENCES

- Allison HE, Hobbs RJ. 2006. *Science and Policy in Natural Resource Management: Understanding System Complexity*. Cambridge University Press: UK.
- Banathy BH. 1996. *Designing Social Systems in a Changing World (Contemporary Systems Thinking)*. Springer: New York, USA.
- Bosch O, Maani K, Smith C. 2007a. Systems thinking—language of complexity for scientists and managers. Proceedings of the Conference on Improving the Triple Bottom Line Returns from Small-scale Forestry. S. Harrison, A. Bosch and J. Herbohn. 18–21 June, 2007, Ormoc, the Philippines.
- Bosch OJH, King CA, Herbohn JL, Russell IW, Smith CS. 2007b. Getting the big picture in natural resource management—systems thinking as ‘method’ for scientists, policy makers and other stakeholders. *Systems Research and Behavioral Science* **24**(2): 217–232.
- Bosch OJH, Nguyen NC. 2011. Establishing the Global Learning Laboratories NET for managing complex problems (Working Paper). Brisbane, Australia, School of Integrative Systems, The University of Queensland.
- Burrows WH, Henry BK, Back PV, *et al.* 2002. Growth and carbon stock change in eucalypt woodlands in northeast Australia: ecological and greenhouse sink implications. *Glob. Change Biol.* **8**: 769–784.
- Cabrera D, Colosi L, Lobdell C. 2008. Systems thinking. *Evaluation and Program Planning* **31**(3): 299–310.
- Cain J, Batchelor C, Waughray D. 1999. Belief networks: a framework for the participatory development of natural resource management strategies. *Environment, Development and Sustainability* **1**: 123–133.
- Elias AA. 2008. Towards a shared systems model of stakeholders in environmental conflict. *International Transactions in Operational Research* **15**(2): 239–253.
- Galanakis K. 2006. Innovation process. Make sense using systems thinking. *Technovation* **26**(11): 1222–1232.
- Henry BK, Danaher T, McKeon GM, Burrows WH. 2002. A review of the potential role of greenhouse gas abatement in native vegetation management in Queensland’s rangelands. *Rangeland J.* **24**(1): 112–132.
- Hung W. 2008. Enhancing systems-thinking skills with modelling. *British Journal of Educational Technology* **39**(6): 1099–1120.
- Ishwaran N, Persic A, Tri NH. 2008. Concept and practice: the case of UNESCO biosphere reserves. *Int. J. Environment and Sustainable Development* **7**(2): 118–131.
- Jackson MC. 2003. *Systems Thinking: Creative Holism for Managers*. John Wiley & Sons: Chichester, UK.
- Takefuda I, Yamanaka T, Stallones L, Motomura Y, Nishida Y. 2008. Child restraint seat use behavior and attitude among Japanese mothers. *Accident Analysis and Prevention* **40**: 1234–1243.
- Keegan M, Nguyen NC. 2011. Systems thinking, rural development and food security: key leverage points for Australia’s regional development and population policy. *Migration Australia (launch issue)* **1**(1): 50–64.
- Krull E, Bray S, Harms B, Baxter N, Bol R, Farquhar G. 2007. Development of a stable isotope index to assess decadal-scale vegetation change and application to woodlands of the Burdekin catchment, Australia. *Glob. Change Biol.* **13**: 1455–1468.
- Land T, Hauck V, Baser H. 2009. Capacity change and performance: capacity development: between planned interventions and emergent processes Implications FOR development cooperation (Policy Management Brief No. 22). Maastricht, ECDPM.
- Laszlo KC. 2001. Learning, design, and action: creating the conditions for Evolutionary Learning Community. *Systems Research and Behavioral Science* **18**(5): 379–391.
- Lee, A. 2009. Health-promoting schools: evidence for a holistic approach to promoting health and improving health literacy. *Applied Health Economics and Health Policy* **7**(1): 11–17.
- Liedloff AC, Smith CS. 2010. Predicting a ‘tree change’ in Australia’s tropical savannas: combining different

- types of models to understand complex ecosystem behaviour. *Ecological Modelling* **221**: 2565–2575.
- Maani K, Maharraj V. 2004. Links between systems thinking and complex decision-making. *System Dynamics Review* **20**(1): 21–48.
- Maani KE, Cavana RY. 2007. *Systems Thinking, System Dynamics: Managing Change and Complexity*. Prentice Hall: Auckland, NZ.
- Mai TV. 2012. Sustainable tourism—systems thinking and system dynamics approaches: a case study in Cat Ba Biosphere Reserve of Vietnam. *School of Agriculture and Food Sciences*. The University of Queensland: Australia. PhD Thesis.
- Meadows D. 1999. Leverage points: Place to intervene in a System. Hartland, VT, USA, The Sustainability Institute.
- Midgley G, Ed. (2003). *Systems Thinking (Volumes 1–4)*. Sage: London, UK.
- Mingers JC. 2006. *Realising Systems Thinking: Knowledge and Action in Management Science*. Springer: New York, USA.
- Newell D. 2003. Concepts in the study of complexity and their possible relation to chiropractic health care: a scientific rationale for a holistic approach. *Clinical Chiropractic* **6**(1): 15–33.
- Nguyen NC, Bosch OJH. 2012. A systems thinking approach to identify leverage points for sustainability: a case study in the Cat Ba Biosphere Reserve, Vietnam. *Systems Research and Behavioral Science* In Press (DOI: 10.1002/sres.2145; first published online 11 October 2012).
- Nguyen NC, Bosch OJH, Maani KE. 2011. Creating 'learning laboratories' for sustainable development in biospheres: a systems thinking approach. *Systems Research and Behavioral Science* **28**(1): 51–62.
- Nguyen NC, Graham D, Ross H, Maani K, Bosch OJH. 2012. Educating systems thinking for sustainability: experience with a developing country. *Systems Research and Behavioral Science* **39**(1): 14–29.
- Nonaka I, Konno N. 1998. The concept of 'Ba': building a foundation for knowledge creation. *California Management Review* **40**(3): 40–54.
- Phan TD. 2011. Optimizing conservation effort for serow, *Capricornis milneedwardsii*, in Cat Ba Archipelago, Hai Phong, Vietnam. School of Geography, Planning and Environmental Management, The University of Queensland. Master of Environmental Management.
- Quatro SA, Waldman DA, Galvin BM. 2007. Developing holistic leaders: Four domains for leadership development and practice. *Human Resource Management Review* **17**(4): 427–441.
- Sawin B, Hamilton H, Jones A. 2003. *Commodity System Challenges: Moving Sustainability into the Mainstream of Natural Resource Economies*. Sustainability Institute: Hartland, USA.
- Senge PM. 2006. *The Fifth Discipline: The Art and Practice of the Learning Organization (Revised and Updated)*. Random House, Inc: New York, USA.
- Smith C, Felderhof L, Bosch OJH. 2007. Adaptive management: making it happen through participatory systems analysis. *Systems Research and Behavioral Science* **24**(1): 567–587.
- Sterman JD. 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill: Boston, USA.
- Systems V. 2011. Vensim program, Ventana Systems UK. from <http://www.ventanasystems.co.uk/>.
- Tassicker AL, Kutt AS, Vanderduys E, Mangru S. 2006. The effects of vegetation structure on the birds in a tropical savanna woodland in north-eastern Australia. *Rangeland J.* **28**(2): 139–152.
- Thomas E, Amadei B. 2010. Accounting for human behavior, local conditions and organizational constraints in humanitarian development models. *Environment, Development and Sustainability* **12**(3): 313–327.
- Umaña A. 2002. Generating Capacity for Sustainable Development: Lessons and Challenges. UNDP, UNDP Choices Magazine.
- UNESCO. 2012. Biosphere Reserves—Learning Sites for Sustainable Development. Retrieved 30th March 2012, from <http://www.unesco.org/new/en/natural-sciences/environment/ecologicalsciences/biosphere-reserves/>.
- UNICEF. 2001. A League Table of Child Deaths by Injury in Rich Nations. Innocenti Report Card, Issue No.2.
- van Langevelde, F, van de Vijver CADM, Kumar L, et al. 2003. Effects of fire and herbivory on the stability of savanna ecosystems. *Ecology* **84**(2): 337–350.
- Walker GH, Stanton NA, Jenkins DP, Salmon PM. 2009. From telephones to iPhones: applying systems thinking to networked, interoperable products. *Applied Ergonomics* **40**(2): 206–215.
- Wilson J. 2004. *Changing Agriculture: An Introduction to Systems Thinking*. QLD, Australia, Print on Demand Centre, University of Queensland Bookshop.