The Risk Informed Decision Support (RIDS) System

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Introduction: The Paris Agreement and Climate Change Adaptation

The Paris Agreement penned in December 2015 provides the essential building blocks for universal action to address climate change. Now, much work is needed to breathe life into the provisions and commitments of the Agreement in order to realise the globally agreed vision to limit temperature rise, build the ability to adapt to climate impacts, and align financial flows toward zero carbon and climate-resilient development.

The Paris Agreement clearly sets a goal to enhance countries' capacity to adapt to climate change, strengthen their resilience, and reduce vulnerability. All countries are expected to undertake adaptation planning and to communicate their actions to the UNFCCC to inform a global stocktake. The development of methodologies, reporting requirements, and modalities for the recognition of adaptation efforts should be aligned, through effective coordination among the various bodies mandated to draft these guidelines. Parties, guided by the Adaptation Committee, now need to provide additional clarity concerning an effective adaptation cycle of improvement, including the way in which the UNFCCC will draw on countries' adaptation communications to assess adaptation needs and determine the support needed to facilitate resilience.

A Guide to Adaptation Issues Across the Paris Agreement
- Balance the provision of finance between adaptation and mitigation;
- All Parties will submit reports showcasing progress made on emissions reductions, adaptation efforts and tracking of support;
- Improve the communication, monitoring, and evaluation of adaptation efforts;
- Conduct and a global stocktake by 2018 and update such every five years;
- Elaborate on the mechanism to contribute to mitigation of GHG emissions and support sustainable development;
- Document and encourage non-market approaches to the work program;
- Define a technical examination process to include adaptation— with the Adaptation Committee engaging directly in the process.
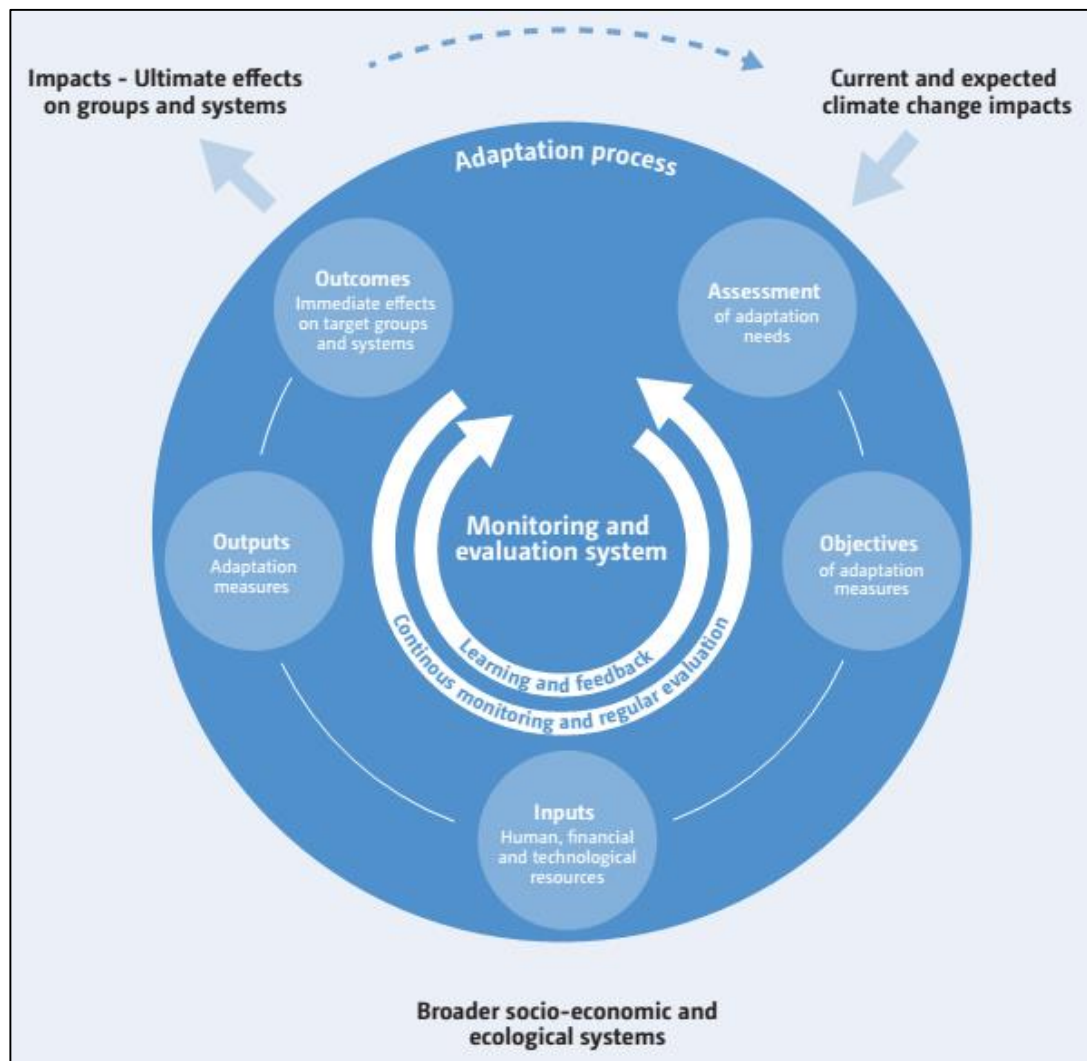
Figure 1: Monitoring and evaluating adaptation. (Adapted from the UNFCCC Adaptation Committee, Enhancing Coherent Action on Adaptation 2012-2015, 2015 Overview Report, Figure 5). Broader socio-economic and ecological systems and impacts-ultimate effects on groups and systems were emphasised.

Introduction to Risk Informed Decision Support (RIDS) System

Risk is inherent in any system; it can be reduced and managed, but it cannot be eliminated. Thus, it would be helpful to understand the risks well enough to make informed decisions to minimise the likelihood of incidents as well as the consequences of an incident if one does occur.

The Risk Informed Decision Support (RIDS) system is a new generation software product of IGCI. RIDS is an integrated system dynamics-based decision support platform with emphasis on risk assessment, management, and governance especially in the climate change adaptation realm. It has been applied for various

risk sectors. RIDS provides a platform for the whole process of risk related climate change adaptation projects and long term planning.

The primary applications of RIDS currently are in climate change adaptation, low carbon development, integrated risk governance realms. GENIES and UrbanCLIM which are earlier versions of RIDS were developed and applied in various projects.

Why a Risk Informed Decision Support (RIDS) system?

Concepts

Applications

Integrated Risk Governance
Orderly Adaptation

Theories

Data

Modelling

RIDS weds the elements and processes of climate change adaptation and integrated risk governance, connecting the realms of idealism, theories, models, data and applications in one platform. RIDS system not only provides guidance framework for the adaptation practice, but also loaded with climate global and local risk data, (including, extreme, variations, and slow onset risks) and tools/models, for detailed assessment work.
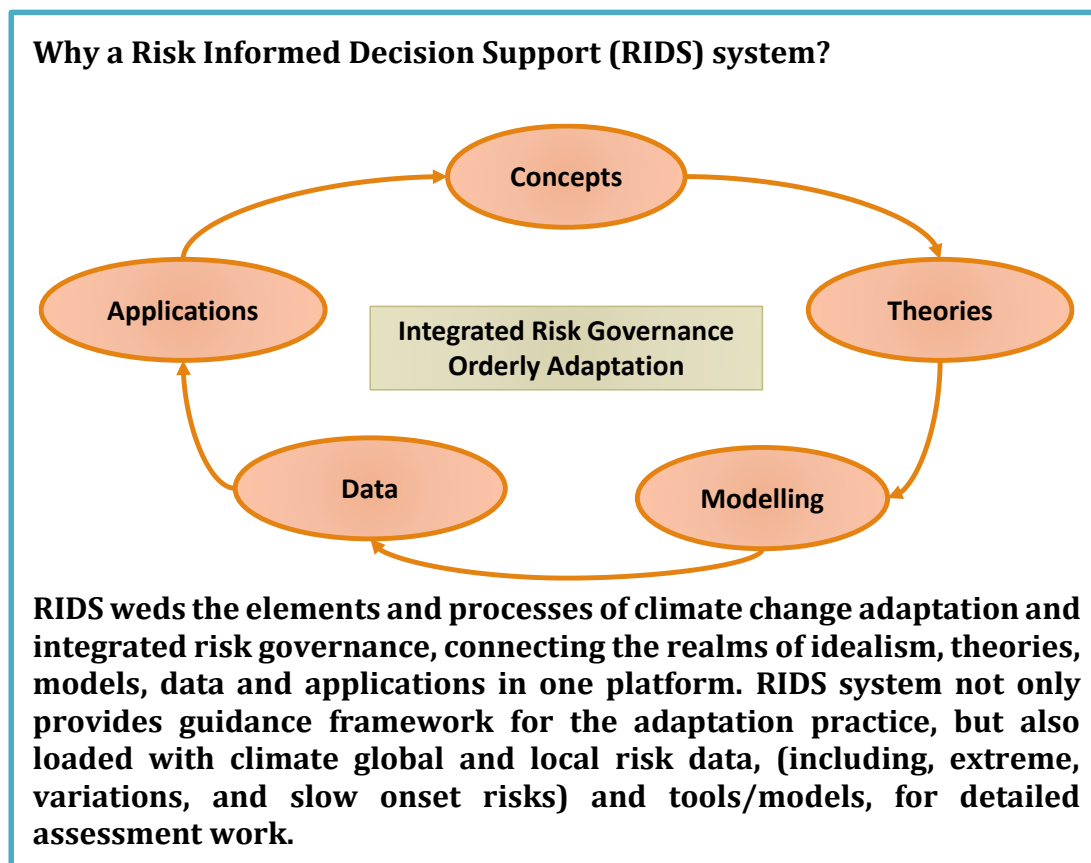
Figure 2: The key elements and the process that are linked via a systems dynamic framework for a comprehensive and transparent approach to climate risk and adaptation assessment and intervention planning.

Features of the RIDS System

Existing RIDS features and the user experiences
The features of the RIDS platform currently include:

- Modular design and standardised technologies to enable building on and linking to existing models and related applications;
- An open framework, allowing for multi-scale, multi-domain impact assessment, which can be customised case-by-case to suit each city/regional planning unit;
- Integrated analysis tools to enable testing of adaptation and mitigation options against socio-economic drivers, likely impacts, and existing goals for sustainable development;
- Climate change uncertainty analysis building on GCM and RCM climate change scenarios;
- GIS interoperability;
- Visualisation and further analysis options for the assessment of results;
- Integration of risk and cost-benefit analysis tools.

User experiences

- Knowledge Base Navigator: A featured navigator tool presents case studies in conjunction with plain-language documentation to enhance understanding of the climate change background and implications of the case study.
- Model Construction and Execution: Users can drag blocks from categorised libraries on a palette to a canvas, then configure and link those blocks together according to the model workflow. Running the model (with pause/resume and abort options) enables the user to quickly verify the correctness of the model, and arrive at analytical results.
- Model Personalisation: Users can add a personal logo to the canvas and embed documentation in the logo block, and can also change the look of custom function blocks.

> *FAQ*
> *How does RIDS link with other models and tools?*
> Via dynamic link libraries, OpenMI, sidecar executables, data exchange, or recoding.
> *How can RIDS handle complicated cross sector systems and multiple issues?*
> **Start from simple**, hide the complexity behind a hierarchical model structure, external model data linkages.
> *How can the models and studies built by one user be transferred to another user?*
> The models and studies can be exported as a standalone package, and then shared with others.
> *How can users contribute to RIDS?*
> Workshop, ideas, models, criticism, project applications.
> *How will RIDS be maintained and updated?*
> Funding and coordination through funding agencies.
> Model, data and knowledge contributions through a Community of Practice (CoP).
> Platform programming through IGCI, CLIMsystems and other partners.

User groups:

- Risk stakeholders - A stakeholder is an individual or organisation that is materially affected by the outcome of a decision or deliverable but is outside the organisation doing the work or making the decision.
- Risk Analysts – A risk analyst is an individual or organisation that applies probabilistic methods to the quantification of performance with respect to the mission execution domains of safety, technical, cost, and schedule.
- Subject Matter Experts – A subject matter expert is an individual or organisation with expertise in one or more topics within the mission execution domains of safety, technical, cost, or schedule.
- Technical Authorities – The individuals within the Technical Authority process who are funded independently of a program or project and who have formally delegated Technical Authority traceable to the Administrator. The three organisations who have Technical Authorities are Engineering, Safety and Mission Assurance, and Health and Medical.
- Decision-Maker – A decision-maker is an individual with responsibility for decision making within a particular organisational scope.

Application Areas:

Risk Management
Climate Change and Risk Management
Sustainable Development and Risk Reduction
Integrated Risk Governance
Risk Informed Planning

RIDS Community of Practice (CoP) strategies

RIDS platform development is one of the core values of the project. Another is the development of a Community of Practice (CoP) – a diverse group of climate change modellers, analysts and decision makers. A CoP serves two critical purposes – the first, directly, is the cross-pollination of ideas, techniques and technologies and the second, indirectly, is to guide the core development of the RIDS platform. More specifically, the RIDS CoP will:

- Promote science-based climate change practice;
- Promote climate change model and tool sharing through a community portal that leverages project management (e.g. SourceForge.net) and Wiki-like mechanisms;
- Provide a conduit for delivering software and information to its members;
- Invite participation and dialogue between inside and outside perspectives;
- Enable broad software development support for climate change adaptation and mitigation;
- Provide a web-based forum for sharing of new knowledge;
- Present workshops on training and software development;
- Enable cross-functional collaboration in projects;
- Enhance public awareness of, and communication with, the CoP.

We have established relationships and communications among major players to enable further collaboration and development of model libraries, tools and application features. With individuals in the climate change research, software development, model development, urban planning and adaptation practitioner roles, these partners include elements of the following groups:
- Regional institutes from China, Korea, Japan, India, Vietnam, Philippines, Australia, USA and New Zealand;
- Research institutes and universities such as IAP, CAS, CSIRO, Yonsei, Ji'nan, Delhi, Nanjing, Waikato;
- International Financial Institutions: ADB, WB; IADB

- International Climate Change Organisations: APN, MAIRS, CORDEX, CMIP, OCMIP, ALM;
- Planning Institutes: Guangzhou, Beijing, New Zealand, Australia, Vietnam, and Philippines;
- Practitioners: Ramboll Environ, CH2M, AECOM, LendlLease, Parson Brinkerhoff, ARUP and ESRI.

An in-depth implementation of RIDS will rely on more collaborative partners to ensure that a wide range of needs are, or can be, met by the platform.
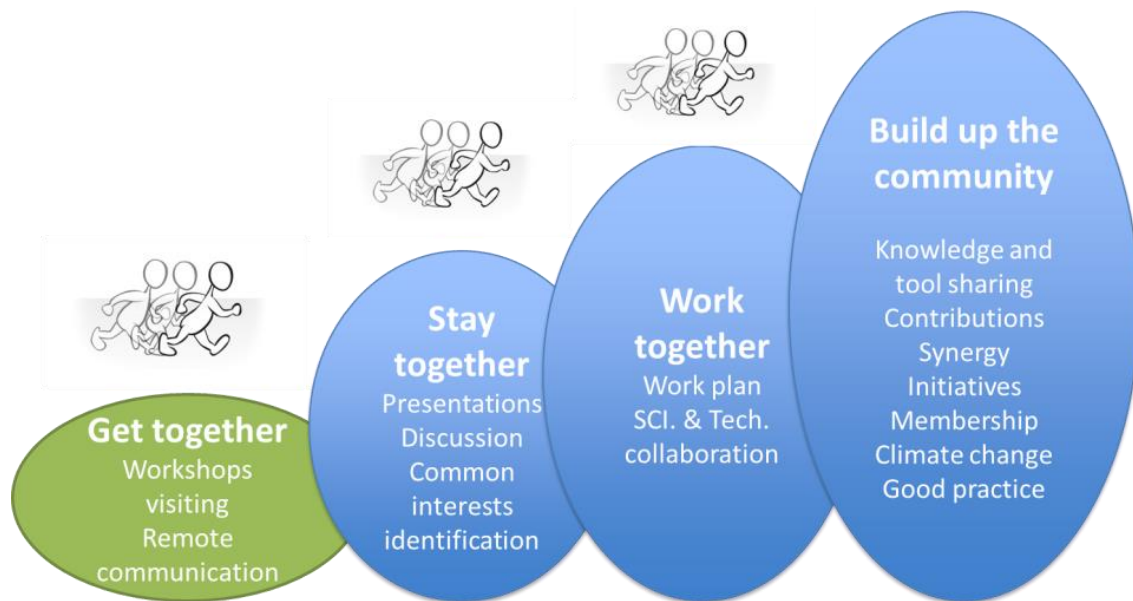

Figure 3: RIDS Community of Practice approaches

RIDS System approaches: system theoretical foundation and applications

(1) System Thinking

System thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static "snapshots." When thinking about climate-change effects, we need to include both regional change and local change and their interactions with trade, food movement, effects on water systems, and how systems will adapt. Understanding such complex systems and their potential evolution is not deterministic modeling. System thinking explores thresholds, tipping points, and sensitivities in the context of science-based and quantitative approaches. System thinking is not yet widespread in modeling efforts although the climate-change community is increasingly acknowledging its importance. In order to enable

system thinking and to support learning organisations, a series of tools and stakeholder engagement strategies need to be prepared and practiced, including: guidance and successful stories, trustworthy relationships, deep engagement, training and long-term follow-up.

System thinking is a major departure from the old way of decision-making in which you would break the system into parts and analyse the parts separately. Supporters of system thinking believe that the old way is inadequate for our dynamic world, where there are numerous interactions between the parts of a system, creating the reality of a situation. According to system thinking, if we examine the interactions of the parts in a system, we will see larger patterns emerge. By seeing the patterns, we can begin to understand how the system works. A risk caused by climate change may become opportunities for the whole systems through reinforce of governance, development, or other adaptation options, these only can be seen or investigated through system thinking.
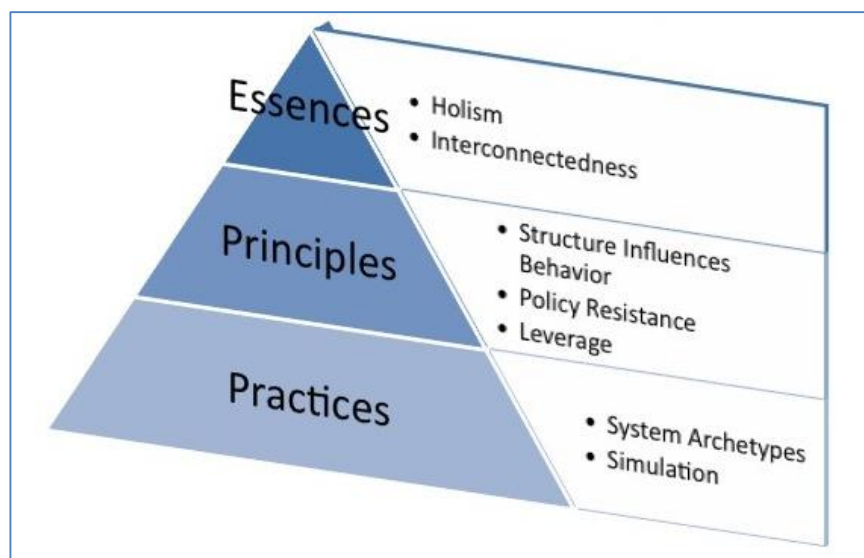

Figure 4: System thinking's essence: principles and practices

Putting Systems Thinking into Practice

How to incorporate systems thinking into practice, a few "principles of practice" for working on complex issues, which we have found to be applicable for both strategy and evaluation work.

Characteristics of complex system	Principles of practice for working on complex issues
Context Context matters; it can often make or break an initiative	Pay particular attention to contextual factors; seek to understand, describe, and/or respond to changes as they occurs
Connections Relationships between entities are equally if not more important than the entities themselves; Everything in a complex system is connected; events in one part of the system affect all or some of the other parts	Understand, describe, respond to, and/or plan to influence the nature of relationships and interdependencies within the system Understanding, describe, respond to, and/or plan to influence the whole system, including components and connections
Patterns Cause and effect is not a linear, predictable, or one- directional process; it is much more iterative; Patterns emerge from several semi-independent and diverse agents who are free to act in autonomous ways	Understanding, describe, and/or respond to the nonlinear and multi-directional relationships between an initiative and its intended and unintended outcomes Understanding, describe, and/or respond to patterns (both one-off and repeating) at different levels of the system
Perspectives A system cannot be fully understood from one perspective; complex problems cannot be solved by any one actor	Triangulate multiple divers perspectives (or lenses) in any research, planning, or reflection process Remain open to different ways of seeing and doing things.

(2) System Analysis

Socio-Ecological-System

Longstanding approaches to solving ecological and social problems are often insufficient to address complex, highly interactive challenges facing our world today. Climate change, species loss, non-point source pollution, and technological and population pressures on scarce resources are all examples of problems that arise in social-ecological systems (SES). SESs are systems that involve both natural/ecological and human/social components that interact to affect system dynamics. Such challenges have led to calls for increasing attention to how societies organise governance and institutions. As an integral component of governance, institutions are of particular interest. Our ability to purposefully change institutions to enhance adaptive governance requires better understanding of how politics, science, and other factors affect institutional change.

A socio-ecological system can be defined as:

- A coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
- A system that is defined at several spatial, temporal, and organisational scales, which may be hierarchically linked;

- A set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
- A perpetually dynamic, complex system with continuous adaptation.

The concept of socio-ecological systems is to emphasise the integrated concept of humans in nature and to stress that the delineation between social systems and ecological systems is artificial and arbitrary. Whilst resilience has somewhat different meaning in social and ecological context, the SES approach holds that social and ecological systems are linked through feedback mechanisms, and that both display resilience and complexity.

Studying SESs from a complex system perspective is a fast-growing interdisciplinary field which can be viewed as an attempt to link different disciplines into a new body of knowledge that can be applied to solve some of the most serious environmental problems today. Management processes in the complex systems can be improved by making them adaptive and flexible, able to deal with uncertainty and surprise, and by building capacity to adapt to change. SESs are both complex and adaptive, meaning that they require continuous testing, learning about, and developing knowledge and understanding in order to cope with change and uncertainty.
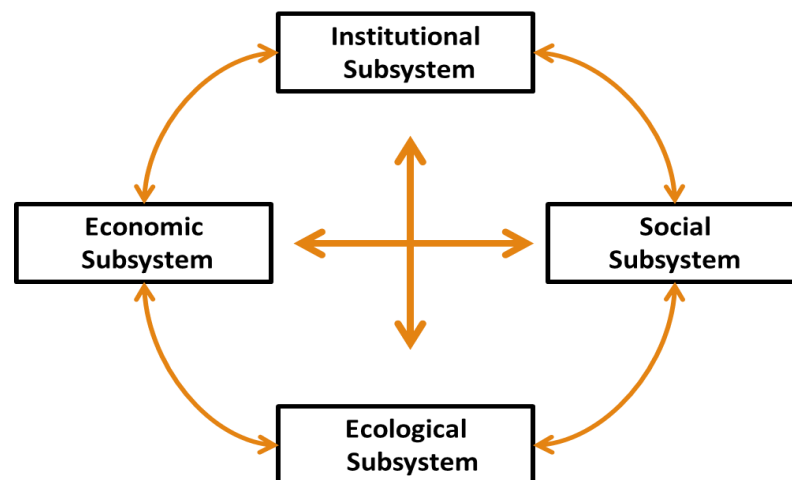

Figure 5: Socio-Ecological System framework and its four subsystems (social, economic, institutional and ecological (natural)) and their interactions are the ideal research topics of sustainability science; they are also the research objectives of integrated risk governance.

SES is typical of large complex systems that differ from a simple system in that it has a number of attributes that cannot be observed in simple systems, such as nonlinearity, uncertainty, emergence, scale, and self-organisation.

- **Nonlinearity**: Nonlinearity is related to fundamental uncertainty. It generates path dependency, which refers to local rules of interaction that change as the system evolves and develops. A consequence of path dependency is the existence of multiple basins of attraction in ecosystem

development and the potential for threshold behaviour and qualitative shifts in system dynamics under changing environmental influences.

- **Emergence**: Emergence is the appearance of behaviour that could not be anticipated from knowledge of just parts of the system alone.

- **Scale** : Scale is important when dealing with complex systems. In a complex system many subsystems can be distinguished; and since many complex systems are hierarchic, each subsystem is nested in a larger subsystem etc. Phenomena at each scale level tend to have their own emergent properties, and different levels may be coupled through feedback relationships. Therefore, complex systems should always either be analysed or managed simultaneously at different scales.

- **Self-organisation**: Self-organisation is one of the defining properties of complex systems. The basic idea is that open systems will reorganise at critical points of instability. The self-organisation principle, operationalised through feedback mechanisms, applies to many biological systems, social systems and even to a mixture of simple chemicals. High speed computers and nonlinear mathematical techniques help simulate self-organisation by yielding complex results and yet strangely ordered effects. The direction of self-organisation will depend on such things as the system's history; it is path dependent and difficult to predict.

Risk and adaptation mapping applying SES

Risk mapping is done to reveal relationships and linkages among the risk (and potential options) factors, in order to map out the structure of a socio-ecological system. In this step the SES framework needs to be applied. The identified risks need to be put into the SES context, to consider the inter-dependency of the four subsystems.
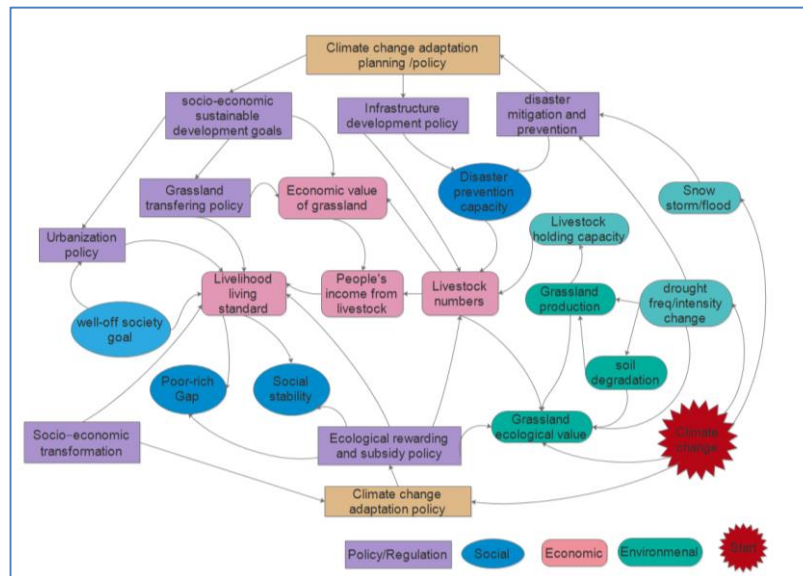
Figure 6: Risk and adaptation mapping of Inner Mongolia peoples' livelihood and grassland under climate change. Different shapes and colours of the text box represent the subsystem's variables interrelationships.

(3) Systems modelling

System modelling approaches include: system dynamics, complex networks modelling, agent-based modeling, integrated modelling, and user friendly tool development, ownership and customisation.
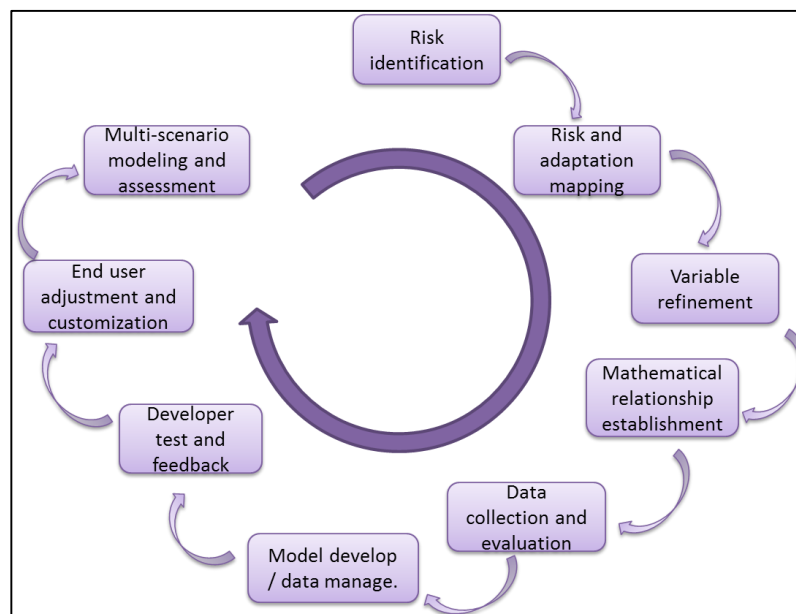

Figure 7: Steps for building a system dynamics model in the RIDS platform.

Step 1: Risk identification

The objective of this step is to create a broad list of climate change risks that might affect your organisation's ability to achieve its goals.

What is "Risk identification"?

This is the process of generating a broad list of reasonably foreseeable ways that climate change stressors could keep your organisation from achieving its goals. It is important to consider all potential risks during the risk identification step. If risks are not identified in this step, they will not be analysed and evaluated in the steps that follow.

Risk identification is normally carried with expert group discussion and brainstorming: experts are the experienced researchers and managers and officers coming from different sectors, their expertise should cover: economic, social, gender, ecological, climate, and institutional aspects. The understanding of the 'real' risk situation is very important.

Methods for identifying risks

Identifying risks is the first and perhaps the most important start step in the risk modelling process. If there is a failure to identify any particular risk then other steps in the risk management process cannot be implemented for that risk.

It is important to realise that an organisation's exposure to risk is likely to be dynamic. For example, at the time that a risk audit takes place, an organisation may not have any sponsorship contracts.

The risk audit may therefore not uncover any risks associated with sponsorship because at the time none were apparent. However some months later after risk management policies and procedures have been documented, the organisation is successful in obtaining a major sponsor and key personnel have not adequately considered risks.

Step 2: Risk and adaptation mapping

This step is to find out the relationships and linkage among the risk (and potential options) factors, in order to map out the structure of socio-ecological system. In this step the SES framework must be applied. The identified risks need to be put into the SES context, to consider the inter-dependency of the four subsystems.

Step 3: Variable refinement

This step helps in the selection of the most important variables and the data availability of these variables is considered. Try to reduce the number of variables and prioritise; otherwise the model could be complicated.

Step 4: Mathematical relationship establishment

The mathematical equations between variables need to be identified from literature, or developed using existing data. The relationship among multiple variables could be very complicated as a sub-model. Appropriate and robust data and mathematical capacity is critical for building a system dynamics model in the RIDS platform.

Step 5: Data collection and evaluation

According to selected variables and equations, related data needs to be collected and evaluated. Whether the data is available and robust can determine the variables to be included/excluded from the model. The data could be statistical, time series, GIS, or ranking or rating (such as, 1-5 in rating),

Step 6: Model development and data management

Use the available mathematical equations, and data to build the model. In this step, critical thinking is needed, because the model needs to be built in the most simple yet logical and robust manner. It is a process of programming. The user can learn from the software manuals, however the most efficient way is to work with modellers who are familiar with the RIDS and programming languages.

Step 7: Developer test and feedback

In this step the model is run to test the model's performance. It normally needs multiple runs for thorough testing and modification in order to attain expected results. The developer must demonstrate the model to end users, seeking their opinions, then either modify or improve the model accordingly.

Step 8: End-user adjustment and customisation

With a running model, end-users can start to adjust the model in order to better understand it, and eventually be comfortable enough with it to customise it: changing UI colours, graph types, logos, etc.

Step 9: Multi-scenario simulation and assessment

The final step is to carry out real simulation and show the scenarios to related stakeholders; they could be either policy makers or peer-researchers.

All steps in a model building process enhance capacity of all concerned on risk assessment, risk management and, integrated risk governance. This process should therefore be iterative with multiple runs.

(4) Systems learning

RIDS supports systems learning to enable the evolution of Communities of Practice, sharing group learning, knowledge cycles, policy and science cycles and social learning processes.
In CCA or IRG projects often transdisciplinary interactions are important. While learning organization of Peter Senge, emphasis on the formed organizations,

system learning concept try to emphasis on the inter-organization, and transdisciplinary natures of CCA or IRG project team, which normally made up with scientists, engineers, policy makers, planner. Therefore, system learning concepts need to be rooted in all level of the team.
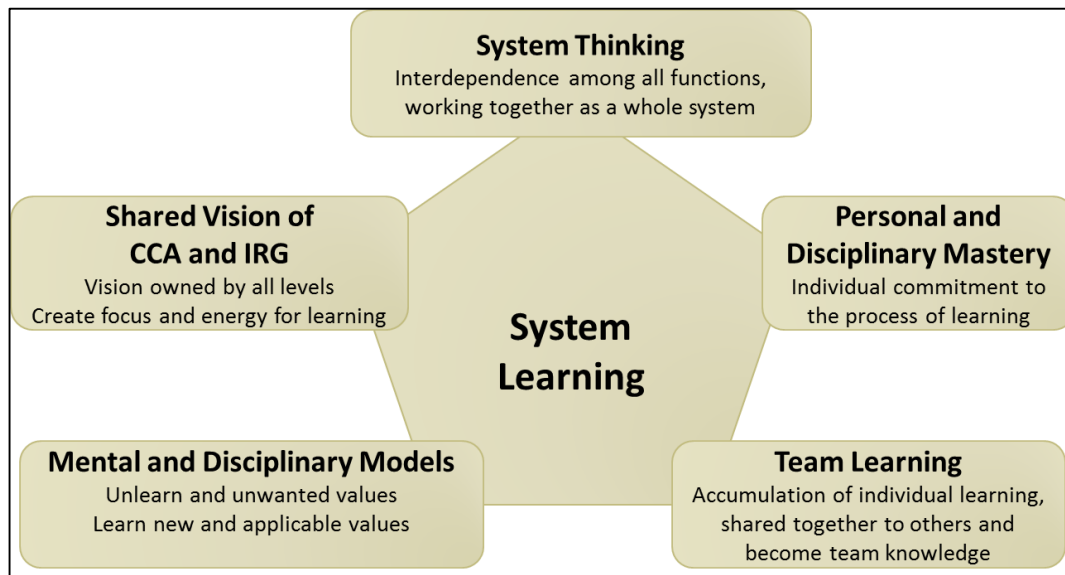

Figure 8: System learning components (modified from the learning organisation concepts of Peter Senge's 'The Fifth Discipline').

A: Building shared vision of climate change adaptation and integrated risk governance

Climate Change Adaptation (CCA) and Integrated Risk Governance (IRG) have to be stated as a vision for everyone in the team, in a clear picture and in an way to inspire the whole team. When there is a genuine vision (as opposed to the all-to-familiar '**vision statement'**), people excel and learn, not because they are told to, but because they want to. But many leaders have personal visions that never get translated into shared visions that galvanise an organisation. What has been lacking is a discipline for translating a vision into a shared vision – not a 'cookbook' but a set of principles and guiding practices.

The practice of shared vision involves the skills of unearthing shared 'pictures of the future' that foster genuine commitment and enrolment rather than compliance. Visions spread because of a reinforcing process. Increased clarity, enthusiasm and commitment rub-off on others in the organisation.

B: Personal and disciplinary mastery.

CCA and IRG are new concepts and practices to most of the experts involved in climate change projects and normally are beyond their expertise in either different traditional scientific or political disciplines. CCA and IRG topics are challenging to everyone, but provide the best opportunities to carry-out system learning.

During the learning process, find the champion rather than a director. System learning only can be realised through individuals who are willing to learn.

Individual learning does not guarantee organisational learning. But without willing individuals, there is no system learning.

Personal mastery is the discipline of continually clarifying and **deepening our personal vision**, of **focusing our energies, of developing patience**, and of seeing reality objectively. It goes beyond disciplinary competence and skills, although it involves them. It goes beyond spiritual opening, although it involves spiritual growth. Mastery is seen as a special kind of proficiency. It is not about dominance, but rather about a calling.

C: Mental models

These are deeply ingrained assumptions, generalisations, or even pictures and images that influence how we understand the world and how we take action. The discipline of mental models starts with turning the mirror inward; learning to unearth our internal pictures of the world, to bring them to the surface and hold them rigorously to scrutiny. It also includes the ability to carry on 'learningful' conversations that balance inquiry and advocacy, where people expose their own thinking effectively and make that thinking open to the influence of others.

D: Team learning

It is about accumulation of individual learning, shared together with others to generate team knowledge. Team learning is viewed as the process of aligning and developing the capacities of a team to create the results its members truly desire. It builds on personal mastery and shared vision – but these are not enough. People need to be able to act together. When teams learn together, not only can there be good results for the team, members will grow more rapidly than could have occurred otherwise.

E: System thinking

Systems thinking – the cornerstone of the whole system learning process

Systems theory's ability to comprehend and address the whole, and to examine the interrelationship between the parts provides, both the incentive and the means to integrate disciplines. A great virtue of Peter Senge's work is the way in which he puts systems theory to work. The Fifth Discipline provides a good introduction to the basics and uses of such theory – and the way in which it can be brought together with other theoretical devices in order to make sense of organisational questions and issues. Systemic thinking is the conceptual cornerstone ('The Fifth Discipline') of his approach. It is the discipline that integrates the others, fusing them into a coherent body of theory and practice.

RIDS Technical Development Strategies

2.1 System dynamics platform

The RIDS platform was built on the system dynamics simulation library "Sage," from Highpoint Software Systems. Sage is a state of the art simulation engine, with powerful simulation capabilities and great flexibility in simulation architecture, control, construction and integration. Built on Microsoft's industry standard .NET technology,

RIDS also uses Windows Presentation Foundation (WPF) technology to implement a friendly, flexible and extendible GUI.

The RIDS architecture was designed to provide robust support for three classes of users – Developers, Modellers and Analysts/Policy Makers. Developers are able to reach into the deepest software layers to extend existing, or build new, simulation, modelling and interactive capabilities that integrate seamlessly with (essentially becoming part of) the RIDS application. Modellers are able to use blocks and connectors, user interaction and model aggregation capabilities to create robust models, and Analysts and Policy Makers use simple and powerful analytical tools that smoothly integrate models and other decision making tools into a decision support engine for formulating practical approaches to real world challenges. Therefore, the RIDS core can act as a generic platform for many other areas other than climate change issues by adding outer components.

The RIDS platform was designed to support layered applications. The central layer of the system provides the fundamental scientific understanding of climate change and related issues, the graphical user interface (GUI) and the model development environment. The interactive layer allows efficient and effective interaction between the model developer and end user. The policy making layer supports policy making processes by providing outputs in a variety of formats, such as graphs, maps, and technical information. RIDS supports a participatory assessment approach through users' dialogue with urban or regional policy makers and planners from targeted cities/regions.
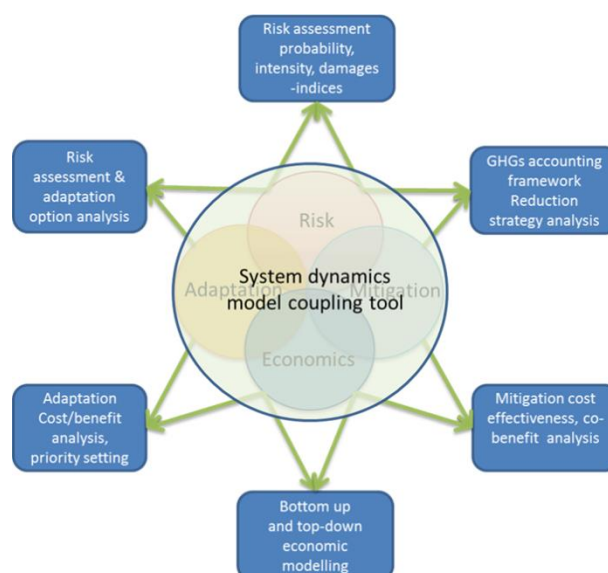

Figure 9: RIDS system dynamics methodologies for climate change applications.

A distinctive advantage of applying a system dynamics approach is the ease with which one can extend and revise models as the domain is explored and questions arise. RIDS

allows in-flight alteration of models and their data and presentations, the use of a visual coupling tools for data conversion, and dynamic updating of workflows. A set of climate change impact models (flood, storm surge, heat waves

and others as identified during the current project), economic models and multiple criteria decision analysis tools are developed and incorporated into RIDS. The flexibility of the system is augmented by established standard model and data libraries that provide the building blocks for a wide range of related applications.
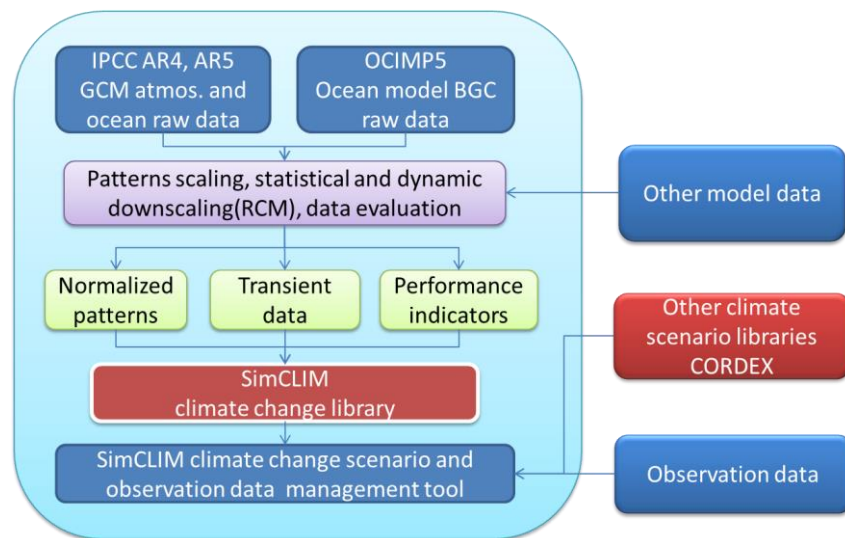

Figure 10: RIDS climate change data library strategy.

2.2 The RIDS database

RIDS has, and will maintain, a comprehensive climate change assessment database which includes up-to-date IPCC GCM, and RCM data for climate change scenarios. These data have been adapted from SimCLIM and other international and national climate change related datasets either directly or using various downscaling methodologies. RIDS will also be able to incorporate other emerging datasets such as RCMs and evolving RCPs scenarios. User defined scenario and empirical data also could be included into the RIDS database if users so desired. The RIDS database will continue to be organically grown and coordinated by Community of Practice partners. From a technology perspective, a central repository will be maintained on an open source system called 'Subversion." Integrated into RIDS, it will enable people to use the data, models and tools from the central repository, but also to non-destructively overlay that content with their own local variants for exploratory, transient or what-if analysis. This allows control of data such that an "official study" can apply nationally/internationally sanctioned models and data, while giving individual organisations the freedom to use their own data/information where appropriate.

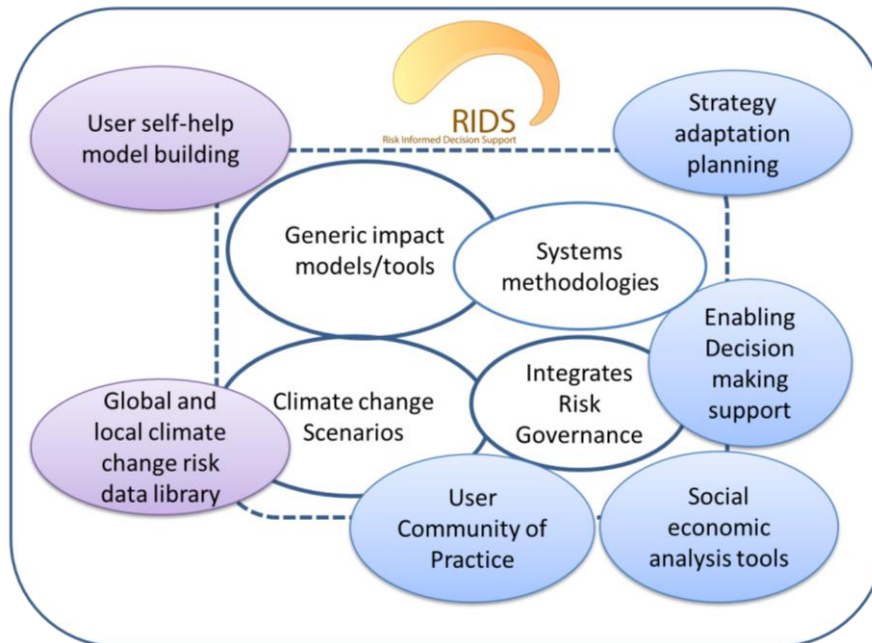## 2.3 RIDS model library development strategies

Figure 11: RIDS model library development strategies.

To help realise a publicly accessible and broadly useful library a cooperatively developed and extended climate change decision support library will evolve. It will includes models tailored to climate change impact and risk assessment for the other major analytical sectors: climate related hazards resilience,

water, transport, and health and others as defined by the CoP. Policy makers and planners from a broad spectrum of end users entities will be part of this cooperative approach. Many models have already been created for these sectors. Through the RIDS Community of Practice, these models and tools can be enhanced and integrated into a standard platform, enabling robust knowledge and technology sharing and transfer. A number of climate change analyses, decision support tools and models have been identified and prioritised for strategic integration into the RIDS platform.

Some models and tools have been demonstrated to stakeholders in China and Vietnam, including a climate change scenario generator, a sea level rise scenario generator, a sea level rise impact model including damage and cost-benefit analysis model, and a decision tree and multiple criteria decision analysis tool. A number of existing models also were identified which can be integrated with RIDS, including extreme event analysis, heat stress modelling, and water resources management tools.
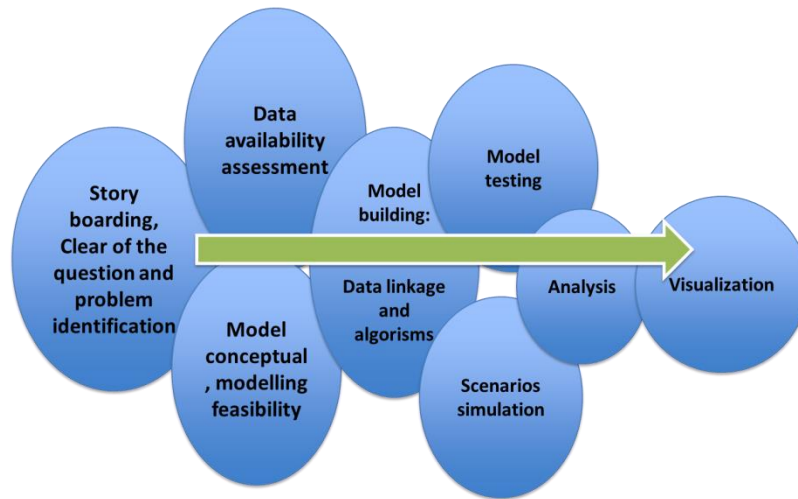
Figure 12: Process for RIDS application building.

2.4 RIDS project manager

The RIDS project manager presents models and studies in an informational setting. Each model and study is presented alongside documentation that explains its use, applicability, limitations, and genesis. A user can dynamically create a new study or project, add documentation and models, and optionally export it for general use, including importing it into a community knowledge base.

The RIDS project manager is intended to:

- Enable decision makers and planners to be more productive, more comprehensive and more correct in a shorter period of time by providing a friendly browser-like environment that speeds the learning curve.
- Provide a common repository for data, models and tools, thereby encouraging active cross-pollination of disparate knowledge, reuse of appropriate models and leveraging of analytical tools across a range of analytical domains.
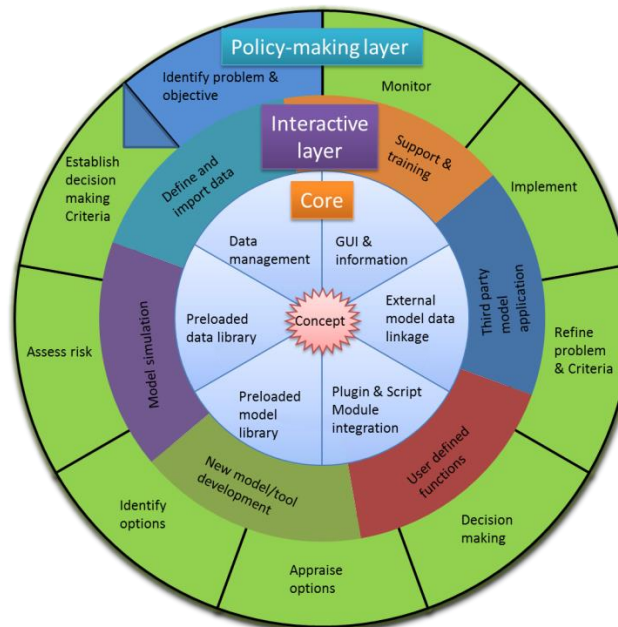
Figure 13: The layered architecture of the Risk Informed Decision Support (RIDS) system. One radiant concept; six core components; six interactive components; nine key stages of policy making process; each component can interact within the layer and between the layers.

Table 2. The core components of the tool

Core 1: Data management	This tool allows the drag-and-drop function which means users can drag the customized data or models to the working window, and the data and model can work immediately after the drop (copy).
	Data management tools enable the import and export of the climate, land and socio-economic data, in time series (monthly, daily, hourly, sub-hourly) or spatial patterns (ARC-GIS grids, and polygon layers, for example).
	The site data manager, data import wizard, and data browser functions all permit the user to freely import site specific or gridded data into the system.
	An area browser allows users to view and edit all the data available in the system.
	Import & export link to other formats for third party software.
Core 2: Preloaded data	All the functions, data and models are linked to the climate change scenarios. This tool provides the basic climate change scenarios at the global level, and can also provide customised local scenarios according to the case study area and users' requirements.
	GCM data, RCM, SD data, historical observation data

	High level background GIS data, shapefiles, population, DEM, river basin, etc.
Core 3: Preloaded models	Models developed from previous work are preloaded into the system for application
	Generic models: such as, water balance model, extreme values analysis, drought index (SimCLIM modules) and others can be developed or linked
	Health impact model (needs to be calibrated before application)
Core 4: Model integration tools	System dynamics approach. Dynamic-Link Library (DLL): new models or function can be developed as DLLs in a certain convention; they can then be dropped into the system and applied.
	Script: type in equations, simple models on screen and carry out the analysis
Core 5: External model/data linkage	Provide data exchange protocol for the models and the tool can be linked to the toolkit.
Core 6: GUI & Information (Help)	Geographical information systems files: shape file, gridded file
	Graph: Excel, Access, database
	Note: user can type their notes and save to working items
	Help & Key message

Table 3. Interactive layer major functions

IL1: Define and import data	Data availability checking, define the baseline data, spatial resolution, master plan or projection future time line.
	Import the required data for model simulation: including: climatic, geophysical, socio-economic, geospatial data
	Geographical information systems files: shape file, gridded file
	Graph: Excel, Access, database
IL2: Model simulation— output	Parameter setting, run models, result checking, graphing, layout
	Parameter setting
	Climate scenario; socio-economic develop-scenario; adaption and/or mitigation option selection, input, cost estimate
	Economic analysis method (cost/benefit, cost effectiveness, co-benefit)
	Target setting
	Run models, result checking, graphing, layout
IL3: New model/ tool development	No suitable model is available in the model library, discuss with the related developer for new model development through in-depth research.
IL4: Model coupling and development Tool	**System Dynamics Methodology**
	Plugin DLL (screen shot), define functions through script functions
	Existing models can be re developed as DLL using a certain convention then plug into the tool for application. Simple equations/ relationship can be typed on the tool interface and to carry out analysis.

	One of the unique advantages of using system dynamics models to study public policy issues or problems is that they can easily be extended or revised to address additional questions as they arise.
	The tool allows users to register different models, input and output of the model, use a visual coupling tool for data conversion, define workflows, run workflows, and monitor workflows.
	The tool will deploy dynamic data conversion techniques for the user-created data mapping schemas using the provided visual tool.
IL5: Link to third party models through linkage functions	Complicated models or heavy computing consuming models which are not suitable to be directly run in the tool, a linkage function would perturb the model input data with climate change projection.
IL6: Technical support and training	It is essential for an appropriate application of the tools. The embedded complexity and uncertainty of climate change information may not be well understood without training or good technical support. Link to project feasibility study tools and finance instruments and guidance.

Resilience

Resilience has been defined as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." The term resilience is applied to a range of topics including physical security, business continuity, emergency planning, hazard mitigation, and the built environment's (e.g., facilities, transportation systems, and utilities) ability to resist and rapidly recover from disruptive events. There are specific research needs for achieving community resilience of the built environment. Community resilience depends upon the capacity of facilities and infrastructure systems to maintain acceptable levels of functionality during and after disruptive events and to recover full functionality within a specified period of time. Natural, technological, and human-made hazards in most environments continue to be responsible for significant losses and damage to built environments. To improve the disaster resilience of communities to hazard events, each community needs to develop plans based on a risk-informed methodology that addresses multiple hazards, system performance levels, recovery of functionality, and dependencies between systems. A risk-informed methodology supports decision making among alternatives for community resilience. Research needs have included risk-informed tools such as RIDS to support resilience planning at the community level, performance goals including functionality and recovery levels, multiple resilience levels, and standardised tools and metrics for community resilience and the built environment.

Risk assessments

Risk assessments are usually commissioned and conducted as part of a risk management and adaptation plan. Assessments usually start with the hazard to identify potential damage scenarios and probabilities and model potential consequences over time and space.

Risk management, on the other hand, encompasses a larger domain and is based on many considerations that are not part of the assessment results. These considerations are explored in detail through case study analysis. It is, however, important to recognise that, in the design and application of risk assessments, they do not automatically translate into either a set of recommendations or plan of action to be taken by decision makers. This 'uptake' needs to be carefully considered within wither the disaster risk management or climate change adaptation plan.

Using risk assessments in decision-making

Risk assessments are important as both products and processes. They can provide valuable inputs to decisions that need to be taken about where to invest or what to insure, and they can also raise awareness among stakeholders about different components of risk. Conducting a risk assessment can increase transparency and it can even be used as a consensus-building tool.

The role of disaster risk assessments may be analysed from a number of different, but complementary, decision-making perspectives:

1) Increase awareness and understanding of disaster risk, thus laying the ground for more attention to be paid to disaster risk management and climate change adaptation.
2) Develop financial applications to spread and transfer risk to the private sector (such as insurance).
3) Guide and inform risk management and adaptation policies and investments at different levels based on decisions about acceptable levels of risk (e.g. for engineers to design construction projects).
4) Inform early warning systems and contingency planning in the development of preparedness and emergency response plans.
5) Inform land-use, urban and spatial planning decisions. Previous studies suggest that risk assessments need to be targeted to specific needs and decisions, at different scales and sectors. For example, a risk assessment conducted with the purpose of engaging communities, communicating risk and promoting local action will have low data requirements and costs compared to an assessment needed to inform risk management policies in either a city or region, or for catalysing growth in the catastrophe risk insurance market.

Scenario Planning and Its Application

Scenario planning is a comprehensive exercise that involves the development of scenarios that capture a range of plausible future conditions. That development is then followed by an assessment of the potential effects of those scenarios on a focal resource or decision, and the identification of responses under each scenario, with a focus on those that are robust across scenarios. Whereas predictions and forecasts are statements about what will happen in the future with some degree of certainty, scenarios are plausible, alternative characterisations of the future not intended to be associated with probabilities. Scenarios can be constructed as qualitative narrative storylines or quantitative expressions of future conditions, depending on the outcomes needed to achieve the goal of the planning effort. While there are a variety of ways to use scenarios in planning, here we focus specifically on the use of multiple future scenarios to embrace uncertainties in decision making as a means for managing risk and maintaining flexibility in current and future decisions.

Scenario planning is particularly appropriate in complex situations where uncertainties about future conditions and the effectiveness of management actions are uncontrollable and irreducible. This can be the case when elements of socio-ecological systems that provide the context for natural resource management have the potential to greatly influence decision outcomes. These elements, or drivers of change are external to the resource and beyond the direct control of managers (e.g., environmental factors, population growth and demographic changes, land use patterns, the availability of financial resources, etc.). Uncertainties that cannot be reduced within a decision timeframe because they are beyond managerial control or outside current scientific knowledge make it difficult or even impossible to develop informative predictive models. Scenario planning offers an alternative approach to considering future conditions as uncertainties and the level of complexity of a situation increases, the longer one looks into the future, and when there is a relatively low level of understanding about the issue.

Scenario planning has received increased attention as a tool to inform natural resource management decisions in light of climate change. Climate change uncertainties range from gaps in our understanding of how climate systems function; whether and how much humans reduce or increase greenhouse gas emissions; what the rate, direction and magnitude of climate changes might be; how natural and human systems may respond to those climate changes; and what will constitute effective management actions in light of those changes. There are also uncertainties surrounding how climate change will interact with other social, economic, political, and technological changes.

Scenario planning is just one method to support planning and decision making under uncertainty, and it can be used in complementary ways with other decision frameworks, methods and tools, such as adaptive management, structured decision making, and iterative risk management. It can be used to serve multiple purposes, including education and outreach, decision support,

and research. While there are key steps in the process, there is no single established methodology for conducting

scenario planning, or even discreet types of scenario planning approaches. It is a method that can be tailored to meet a wide variety of needs and available time, capacity, and financial resources.

General Principles and Benefits of Scenario Planning

Scenario planning is appropriate to use in situations of high uncertainty and low controllability, to examine different future trajectories and anticipate surprises

Scenario planning explores plausible—not always the most probable—futures

- Identifies key drivers of future change and the underlying assumptions to provide greater transparency
- Assumes that future boundary conditions are not necessarily the same as those that currently influence a system
- Builds awareness of multiple pathways toward the future

Scenario planning is underpinned by strategic thinking on how decisions of today limit future options

- Facilitates a move away from traditional single-outcome planning
- Allows the exploration of plausible future developments of potential importance to current and future decision-making
- Challenges thinking on current management actions

Scenario planning is not a "one size fits all" approach; there are multiple ways to design a scenario planning exercise

- Combines qualitative and quantitative information to describe changes to future environmental conditions
- Synthesises and integrates issues across sectors and scales in a common framework
- Fosters consistency in characterising future conditions across diverse studies, spanning different sectors, regions and scales of analysis, to enable direct inter-comparison of results
- Provides a common logic to integrate key drivers of change, as well as their impacts and interactions
- Outcomes may be very technical (e.g., computer simulation), as well as creative, depending on project need

Scenario planning facilitates participatory learning and understanding

- Fosters improved learning and imagination;
- Can help participants collaboratively create a narrative or storyline;
- Moves away from a single dominant perspective toward acceptance of unfamiliar but valuable ideas;

- Can help create powerful stories to share with stakeholders outside of the planning process.

Scenario planning is a living process, requiring us to revisit key plausible futures to validate, replace, or remove them as we gain knowledge

- Embeds a future-oriented perspective into organisational and individual thinking and operations.

Key Questions to Address when Considering an Adaptation Strategy

Question
1. What is the goal of the adaptation strategy? In the case of floods, for example, it is possible to: a. Maintain the current level of risk b. Reduce the level of risk despite climate change (if the risk is considered too high) c. Limit the increase in the level of risk due to climate change In the case of agriculture, for example, an adaptation strategy could: a. Aim to maintain the current type and level of production (e.g., through irrigation) b. Promote a transition to other crops, for example, ones that require less rainfall Once the goals have been decided, efficiency criteria can be set for use in the review process.
2. Does the adaptation strategy take into account the varied timeframe over which climate hazards occur? a. "Adaptation gaps" (i.e., what needs to be done regardless of climate change) are immediate-term needs to ensure that the sub-national territory has adapted to the current climate (for example drainage systems that are adequate to cope with the current level of precipitation) b. Adaptation options that can be operationalised in the short-to medium-term: for example, plans to adapt to phenomena such as heat waves and droughts that will occur in the immediate- to medium-term c. Adaptation options that are needed in the context of managing issues that are likely to be problematic in the future, over different time scales— the next 5, 10, 15, 20, 30, 50 years and so on. For example, new urbanisation plans to adapt to gradual sea level rise or industry developments in the context of likely decreasing viability of the effectiveness/productiveness of specific sectors as the climate changes
3. Is the adaptation strategy a no-regret/low-regret solution? (This means one that yields immediate benefits even in the absence of climate change) More efficient and effective water management, for example, may lead to cost reductions/savings and health benefits that promote a developmental improvement for the sub-national territory, regardless of climate change. Consideration must be given to all the unintended and likely unintended consequences of such strategies, including cross-sectoral implications. Promoting the use of air-conditioning, on the other hand, is not a no-regret/low-regret solution, as its use requires more intensive energy use, which in turn contributes to climate change.

4. Is the adaptation strategy flexible and reversible?
This is important given the uncertainty inherent in projecting future climate change – if parameters turn out to be different from what is currently projected, will it be possible to adjust the strategy accordingly?
The strategy and measures must be robust to a range of potential climate change scenarios.

5. Consistency with other sub-national territory goals?
Sub-national planners in particular will be aware of the plethora of planning and developmental goals in their area. It is important to ensure that the adaptation strategy is consistent with other goals over the short, medium and long timescale. For example, does adaptation option have a positive or negative impact on poverty reduction?
Does it fit into the short term planning goal for the sub-national territory?
Does it fit in with nationally-promoted sustainable development strategies?

Risk governance

Risk governance deals with the identification, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms and is concerned with how relevant risk information is collected, analysed and communicated, and how management decisions are taken. It applies the principles of good governance that include transparency, effectiveness and efficiency, accountability, strategic focus, sustainability, equity and fairness, respect for the rule of law and the need for the chosen solution to be politically and legally feasible as well as ethically and publicly acceptable. Risk accompanies change. It is a permanent and important part of life and the willingness and capacity to take and accept risk is crucial for achieving economic development and introducing new technologies. Many risks, and in particular those arising from emerging technologies, are accompanied by potential benefits and opportunities. The challenge of better risk governance lies here: to enable societies to benefit from change while minimising the negative consequences of the associated risks.

Sound risk governance minimises:
- Inequitable distribution of risks and benefits between countries, organisations and social groups;
- Differing approaches to assessing and managing the same risk;
- Excessive focus on high profile risks, to the neglect of higher probability but lower profile risks;
- Inadequate consideration of risk trade-offs;
- Failure to understand secondary effects and linkages between issues;
- Cost of inefficient regulations;
- Decisions that take inappropriate account of public perception;
- Loss of public trust.

IRGC's risk governance framework is a comprehensive approach to help understand, analyse and manage important risk issues for which there are deficits in risk governance structures and processes. The framework comprises five linked phases:
1. Pre-assessment
2. Appraisal

3. Characterisation and evaluation
4. Management
5. Communication

These interlinked phases, which are summarised in the following pages, together provide a means to gain a thorough understanding of a risk and to develop options for dealing with it.
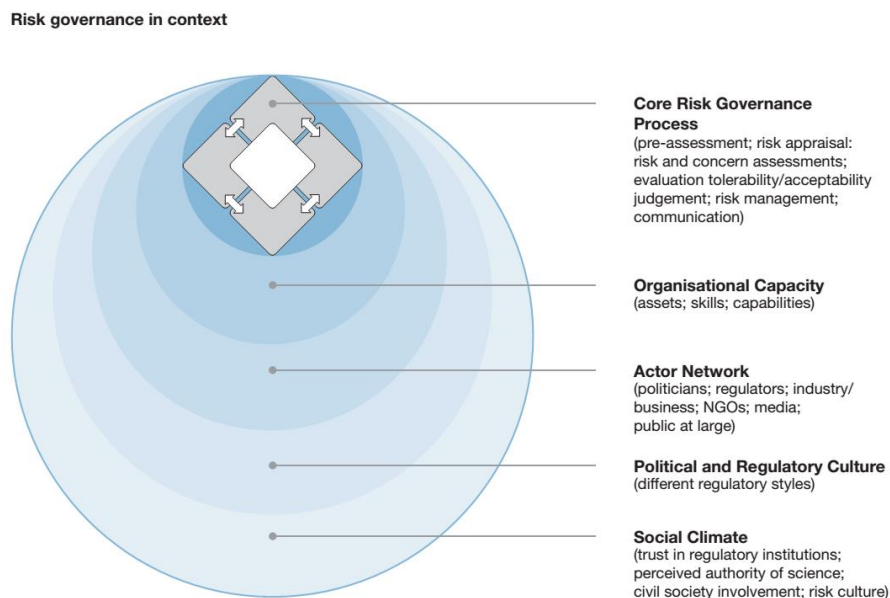

Figure 14: Widening the risk-governance horizon‐ the importance of context.

Alongside the conventional elements of risk assessment, risk management, and risk communication, the framework stresses the broader social, institutional, political and economic contexts that must be taken into account in risk-related decision-making.

Risk communication

Risk communication is a fundamental element of a sound risk management framework. Notification of the public about major hazards and threats, to which they may be exposed, should be a basic responsibility of governments. Increasing the awareness of households, businesses and communities about their hazard exposures and vulnerabilities, as well as the specific measures they could take to prevent, mitigate or prepare for them is the essence of risk communication. Such information spurs informed debate on the need for investments in prevention, mitigation and preparedness, and is thus a key element of good governance in risk management policy.

Some survey evidence suggests that more could be done across all countries to raise risk awareness through better risk communication. For example, the

results of a survey of 1 700 companies in the Loire river basin in France showed that 53% of the business owners whose activity was located in a flood zone admitted to being completely unaware of their exposure (OECD, 2010). Low levels of awareness about existing hazards and the responsibility to take protective measures are endemic to low levels of resilience, meaning the capacity and speed of regaining function after a disruption.

Ineffective risk communication can lead the public either to underestimate risks, which may result in taking insufficient precautionary measures, or to overestimate risks, which often leads to suboptimal allocation of resources. Despite concerted government actions to raise and maintain awareness of hazards and threats, there are significant divergences between experts' understanding of risks and the general public's perception of risks. Few countries find that risk communication efforts fully achieve their desired objectives, yet many countries continue to use the same techniques that have failed them in past, in the hope that the target audience will pay more attention. There is value and opportunity, therefore, to identify novel practices and techniques of effective risk communication practices across similarly situated countries and to test hypotheses for policy transfer.

Risk communication needs to be a key priority for improving future risk management. For example, the EU Council Conclusions from 13-14 December 2011 on risk, emergency and crisis communication emphasised the need for risk communication to enable citizens to recognise risks and take subsequent actions that reduce their potential exposure. The Recommendation recognised the importance of interaction and coordination among public authorities, international organisations, NGOs, citizens, the media, businesses and citizens' associations, including trade unions, to make risk communication effective. Finally, the Conclusions acknowledge the usefulness and importance of new communication technologies and interactive information channels such as social media as instruments to be considered in risk communication strategies, taking into account cultural, social, linguistic, economic, risk and technical conditions in different countries and localities.

Similarly, the OECD Council Recommendation on Governance of Critical Risks recommends "a whole-of-society approach to risk communication and facilitate transboundary co-operation using risk registries, media and other public communications on critical risks" and proposes a two-way communication between government and stakeholders, combining targeted communication with the provision of incentives and tools for stakeholders to invest in resilience measures.

The Third recommendation sets out a set of criteria for effective risk communication:

- **Consistency**: it is fundamental to ensure that risk information is consistent across the different risk communication tools. Inconsistencies in this domain can lead to ineffective policies, lack of trust and inaction.
- **Two-ways communication**: risk communication should not be seen as only transmitting expert knowledge to the public. More interactive approaches bring together the public with risk managers to engage in an exchange of risk information. It allows inter alia to engage more actively the stakeholders in risk reduction efforts, to collect more broad information about risks and to evaluate the efficiency of risk communication tools through feedback loops.
- **Accuracy and trust**: risk communication should be based on the best available knowledge on hazards, threats and vulnerabilities. Full transparency about the level of accuracy is necessary to ensure that risk information is trusted and acted upon.

- **Accessibility**: while risk communication supposes dedicated and targeted actions, citizens and business should also be provided with easy-to-use and accessible risk information portals and repositories.
- **Adaptation to audience**: dedicated risk communication should target specific segments of society, from national to local levels, vulnerable groups, children and elderly, communities, and non-residents (e.g., tourists) in ways that are adapted to both their cognitive capacities and their specific exposure or vulnerabilities.
- **Cross-sectoral and transboundary**: risk communication should incorporate information from different sectors so that the public has a clear picture of the multiple dimensions of potential hazards and threats, and their potential cascading effects. Consistency across regional and/or national borders to communicate about risks should also be addressed; both for cross-border hazards and also to ensure that investors, travelers, tourists and other stakeholders can understand risk information in other countries.

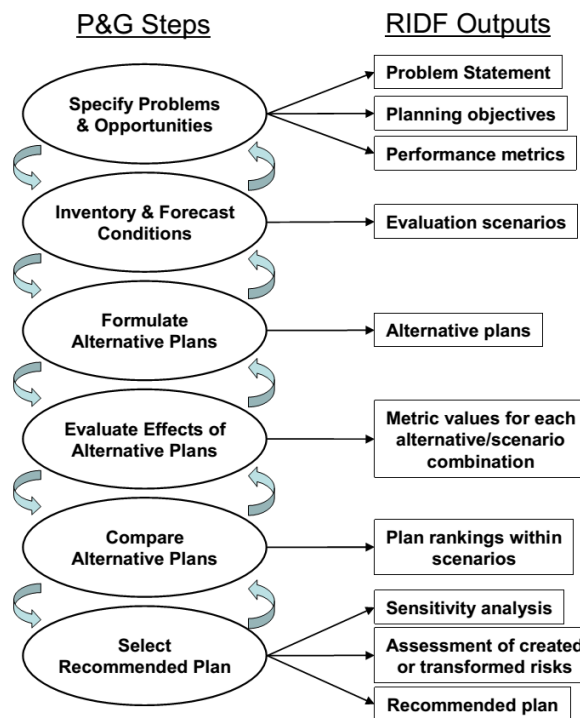**Risk Informed Decision Framework (RIDF) planning process as follows:**

Figure 15: Risk-Informed Decision Framework.

1. Specify Problems and Opportunities:

Frame the decision by developing a problem statement and identifying the spatial and temporal boundaries of analysis (i.e. planning area and planning units).

Establish planning objectives and choose outcome measures of performance, or metrics, which reflect progress toward achieving the planning objectives.

2. Inventory and Forecast Conditions:

Select models of physical and economic systems or other appropriate tools to simulate decision outcomes in terms of the selected performance metrics. Identify important sources of uncertainty in physical and economic models.

3. Formulate Alternative Plans:

Formulate decision alternatives by identifying potential measures for flood risk reduction, pre-screening poor performing measures, and formulating an array of alternatives planning unit from remaining measures.

4. Evaluate Effects of Alternative Plans:

Model the outcome measures of performance for each alternative and each scenario.

5. Compare Alternative Plans:

- Obtain weights on metrics from the decision makers and/or stakeholder groups.
- Calculate multi-attribute utility and implement the stakeholder preference analysis for each alternative and scenario.
- Identify consistently dominating plans in each planning unit based on the multi-attribute utility values.
- Develop alternative ranking of plans based on assessment of evaluation criteria addressing other decision objectives viewed as important to decision makers.
- Conduct an indexed scoring of alternatives based on the MCDA results and alternative plan rankings.
- Identify the final array of alternatives for each planning unit and prepare detailed tradeoff analysis of plan performance and outputs for these alternatives.
- Apply secondary evaluation criteria and sensitivity analysis (e.g., varying levels of participation in nonstructural measures and analysis of alternatives under degraded coastal conditions).
- Screen out plans that are consistently dominated.

6. Select a Recommended Plan:

- Develop strategies for combining top performing alternatives in each planning unit to create comprehensive plans.
- Develop conclusions and findings based on the above analyses.