HKKH Partnership
for ecosystem management

Decision Support Toolbox

for Systemic Planning and Management of Mountain Ecosystems

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cesvi EvK2CNR ICIMOD IUCN Supported by Cooperazione Italiana allo Sviluppo Ministero degli Affari Esteri

Institutional Consolidation for the Coordinated and Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the HKKH Mountain Complex

About ICIMOD

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Cover photo: Birendra Bajracharya

Acronyms

DDC	District Development Committee
DNPWC	Department of National Parks and Wildlife Conservation
DSS	Decision Support System
DST	Decision Support Toolbox
ESRI	Environmental Systems Research Institute
GIS	Geographic Information System
GUI	Graphic User Interface
HKKH	Hindu Kush-Karakoram-Himalaya
I/NGO	National and International Non-governmental Organization
ICIMOD	International Centre for Integrated Mountain Development
IDE	Integrated Development Environment
IWP	Integrated Web Portal
KACC	Khumbu Alpine Conservation Committee
MoFSC	Ministry of Forests and Soil Conservation
MRE	Model Runtime Environment
NTFP	Non Timber Forest Product
P3DM	Participatory 3D Modeling
PA	Protected Area
QM	Qualitative Model
RDBMS	Relational Database Management System
SA	Spatial Analysis
SDM	System Dynamics Model
SNPBZ	Sagarmatha National Park and Buffer Zone
SPCC	Sagarmatha Pollution Control Committee
VDC	Village Development Committee
XSLT	EXtensible Stylesheet Language Transformation

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Introduction

1.1 Background

The main aim of the HKKH (Hindu Kush-Karakoram-Himalaya) Partnership project was to contribute to the consolidation of institutional capacity for systemic planning and management at the local, national and regional levels, focusing on poverty reduction and biodiversity conservation (Amatya et al 2008; www.hkkhpartnership.org). Its specific objectives include providing tools and instruments to establish a process for the application of Decision Support System (DSS) in mountain protected areas (PAs).

Many DSSs have evolved over the past few decades to help managers in this process. Although DSS may be interpreted loosely as any system that supports a decision in any way, more formally they are defined as "interactive computer-based systems that help decision makers utilise data and models to solve unstructured problems" (Sprague and Carlson 1982). In the field of natural resources management, DSSs have evolved to encompass multi-component systems that include various combinations of simulation modeling, optimisation techniques, heuristics and artificial intelligence techniques, geographic information systems (GIS), associated databases for calibration and execution, and user interface components. An assessment of existing DSS packages oriented towards ecosystem management suggested that a large majority were either in the realm of research or addressed very specific applications while very few of them were relevant for supporting the objectives of the project. No single DSS has been found to be capable of fully addressing the broad range of issues involved in the management of protected area. In this context, the project initiated the concept of the Decision Support Toolbox (DST) as a collection of tools and methods to address the needs of different stakeholders to support key components of the decision-making process.

The DST includes hard and soft system methodologies, such as computer-based and participatory tools. Sagarmatha National Park and Buffer Zone (SNPBZ) has been taken as a pilot case for the development of DST by the project. The management of SNPBZ is a complex task involving the conservation goals of the park and livelihood options of the people living within it. With many settlements located inside the park and a well established role of the buffer zone management council in decision making, a higher level of coordination is required between the park authority and the local communities. Participatory approaches have been used as the effective way to develop shared understanding of issues and decision-making processes. Besides involving local stakeholders and park authorities in a number of consultative meetings, the participatory research carried out by the project included scenario planning (Daconto and Sherpa 2007), participatory 3D modeling (P3DM) and qualitative system analysis (ICIMOD and CESVI 2007). Similarly, as a hard system methodology, the DST software was designed and developed to provide a set of integrated but self-contained computer-based tools to support decision-making process. Efforts were made to link both hard and soft system tools to ensure a smooth flow of information between the conceptualisation phase of the system and its quantitative analysis, and between the people's needs and the development of solutions (Salerno et al 2008). The development of DST is seen as a part of an institutional consolidation process, which inevitably provides a framework for monitoring the socio-ecological dynamics and a platform for participatory consultation and analyses resulting in a better understanding of the problems.

1.2 Management of protected area as complex system

Like many other natural systems, ecosystem exhibits characteristics of a complex system. System is usually characterised by components (state variables or stocks), and interactions between them in the form of flows of matter, energy or information (Limburg et al 2002). In complex systems, the interactions between the components are strong and usually non-linear and such systems contain complex feedback loops making it difficult to distinguish cause from effect and significant time and space lags, discontinuities, thresholds and limits (Costanza et al 1993).

The project has introduced system dynamics approach for studying different aspects of ecosystem management in mountain protected areas. This approach involves developing system dynamics models that can simulate and quantify the behavior of the system over time and thereby facilitating the process of understanding the complex interrelationships existing between different elements within a system (Elshorbagy et al 2005). Despite the strength in representing temporal processes, the system dynamics models do not adequately represent spatial processes (Ahmad and Simonovic 2004) and more often, they are not designed to work with geographically distributed systems (Miller et al 2005). GIS, on the other hand, is an obvious choice when it comes to handling the spatial problem. However, despite the addition of many sophisticated range of spatial analysis and modeling tools in recent years, the GIS software systems still lack multi-dimensional space-time modeling capabilities (Maguire 2005) and the modeling tools available in GIS software systems are often unable to handle a full integration of spatial dynamic processes (Mazzoleni et al 2003). Therefore the integration of GIS and system dynamics provides a logical alternative to model spatial dynamic systems (Ahmad and Simonovic 2004) and thereby helps the decision makers to have a better understanding of the problems and issues related to ecosystem management. The DST software was therefore conceived to facilitate the exploration and assessment of ecosystem management through modeling process and its integration to GIS.

2

User/Stakeholder Analysis

The project carried out the Stakeholder Analysis for SNPBZ. The study identified the following stakeholders and user groups.

2.1 Identification of stakeholders

The project has identified more than 30 stakeholders in SNPBZ who can be classified into major groups as given in the table below:

Table 1: Major groups of stakeholders in SNPBZ (CESVI 2006)

Group	Stakeholder
Government agencies (Central and local)	Department of National Parks and Wildlife Conservation (DNPWC), SNP Office, Ministry of Forests and Soil Conservation (MoFSC), Ministry of Culture and Civil Aviation, Ministry of Tourism, Nepal Tourism Board, District Development Committee (DDC), Village Development Committees (VDCs), District level line agencies
CBOs (formal governance bodies, resource management bodies, public interest bodies)	BZ Management Committee, BZ User Committees, BZ User Groups, Community Forestry User Groups, Women's Group, Mothers' Group, Sagarmatha Pollution Control Committee (SPCC), Khumbu Alpine Conservation Committee (KACC), Himalayan Trust, Porters' Progress, Eco-club, Health clinics
Business organisations	Hotel and lodge owners, local shopkeepers, travel/ trekking agencies, trekking porters, guides, Sherpa mountaineers, yak drivers, farmers

National and international non-governmental organisations (I/NGOs)	Himalaya Rescue Association (HRA), Trekking Agencies Association of Nepal (TAAN), Nepal Mountaineering Association (NMA), World Wildlife Fund (WWF), ICIMOD, IUCN, EV-K2-CNR, CESVI
Research and academic institutions	National Academy of Science and Technology (NAST), Resources Himalaya, Tribhuvan University, Kathmandu University, Researchers
Cultural and religious organisations	Monasteries, nuns and monks
Others	Tourists/visitors, journalists, foreign tourism business and overseas travel agencies, cross-border traders

From the functional point of view, the stakeholders can be classified into nine different groups as given in the following table:

Table 2: Stakeholder functional groups and roles

Functional group	Include	Role
Management agencies	DNPWC, SNP Office, Nepal Army	Overall management of protected area
Implementing agencies	BZMC, BZUC, BZUG, CBOs, Local NGOs	Execution of projects and programs
Central level organisations and line agencies	Ministries, DDC, DFO, DLDO, DAO, VDC, DADO, Eight Party Alliance (EPA)	Policy formulation and monitoring
Conservation partners	WWF, ICIMOD, IUCN, NTB, SPCC, NMA, CESVI, EV-K2-CNR	Fund raising and collaboration in environment management and sustainable development
Supporting projects	SCAFP, TRPAP, HKKH Project	Support park activities
Research and academia	TU, KU, NAST, Academia, Researchers	Knowledge generators, Independent think-tanks
Tourism industry	Hotel, Travel, Mountaineering agencies	Non-consumptive use
Service providers	Tour guides, local shopkeepers, porters	Service providing
Beneficiaries	Local People, Visitors, cultural and religious groups and entrepreneurs	Use of economic and ecological services

2.2 Interaction between stakeholders

The stakeholders identified earlier may have various forms of interactions amongst themselves as shown in Figure 1.

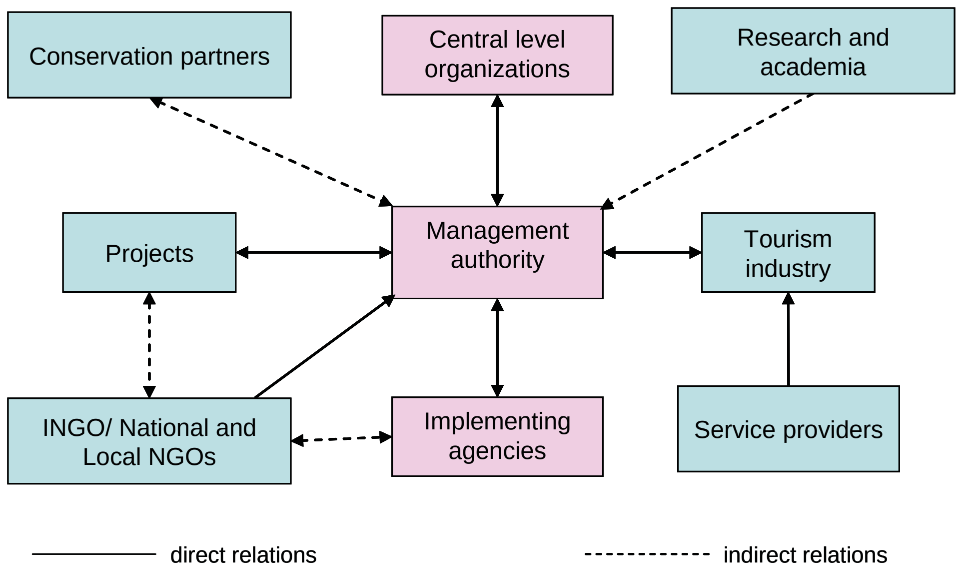

Figure 1: Possible interactions among the stakeholders

2.3 Major users of overall Decision Support Toolbox

Sagarmatha National Park (SNP) Office is the main agency responsible for conservation and management of SNP. The SNP office works under close supervision of Department of National park and Wildlife Conservation (DNPWC) and has direct relations with the Nepal Army, buffer zone management committee, tourism industry, local non-governmental organisations (NGOs) and projects. Research institutions and conservation partners have also been involved in many instances for the betterment of the park by applying sound ecological and scientific principles. Table 3 below shows the major users of DST and their responsibilities:

Table 3: Major users of overall Decision Support Toolbox and their responsibility

Actor	Major responsibility
DNPWC	
Director General/Deputy Director General	Supervision, control and coordination
Ecology Section - Ecologist - Assistant Ecologist	Research and ecological database
Conservation Education Section - Conservation Education Officer - Assistant Conservation Education Officer	Conservation education and public awareness
Management Section - Management Officer - Assistant Management Officer	Tourism and buffer zone management
Planning Section - Planning Officer - Assistant Planning Officer	Planning, monitoring and evaluation
Park Office - Chief/ Conservation officer	Management of a protected area
Others	
Nepal Army	Security and protection of the park
Visitors	Users of information and other services
Local people	Beneficiaries, harmonised users
Researchers	External users and generators of data and information

2.4 Sample use case: Sagarmatha National Park

This sub-section presents a sample use case illustrating specific issues and dynamics of SNP. Although the individual stakeholders may be different in the three pilot areas, they will generally belong to one of the broader groups identified earlier.

Actors

The major stakeholder groups that were identified earlier, and their values and concerns are summarised in Table 4:

Table 4: Stakeholders and their concerns in SNPBZ

Stakeholder groups	Values and concerns
Government agencies Central level Local level	Legislative framework Livelihood of the population Conservation of natural resources Partnership
Community Business Organisations (CBOs) Formal governance bodies Resource management bodies Public interest bodies	Participation in planning Participation in management Livelihood
Business organisations	Stable environment Facilities and infrastructure Business
NGOs	Participation Local culture Conservation Environment Women empowerment Education
Research and academic institutions	Research Technology development and transfer Information and dissemination
Cultural and religious organisations	Religion Culture and tradition Historical heritage
Others	Business Tour

The stakeholders listed on Table 4 are involved at different levels in influencing management decisions. Some of the local level stakeholders, such as cultural and religious groups, CBOs and business organisations, will be involved during the participatory processes. The most likely users of the DST software are government agencies at central and local levels, (non-governmental organisations) NGOs and research and academic institutions. There will also be a group of external users who are not direct stakeholders, but will interact with the knowledgebase and analytical outputs of the system.

Roles

During the interaction with the DST software, these stakeholders will play different roles. The relationship between stakeholders is diverse, with one stakeholder potentially playing many roles, and conversely, many stakeholders playing one role. The different roles played by the stakeholders are identified as follows:

1. Decision Maker

The major decision makers in park management are the government institutions. These can be at the following levels:

- Central level (national level conservation policies and decisions) or
- Local government bodies at the park level (park office, local councils).

2. Thematic Expert

The role of thematic expert is to provide thematic inputs to the DST software, contributing to the qualitative model development and knowledgebase, as well as identifying indicators and defining spatial analysis procedures, among other assistances.

3. Technical User

The technical user can have different functions requiring different expertise. They are:

- Data entry operators update the system database, both spatially and non-spatially.
- GIS analysts perform spatial data editing and analysis.
- Modelers build computer models based on the qualitative models.
- Database administrators build and perform queries on databases and knowledge bases.
- System administrator maintains the regular functioning of the system.

4. Researcher

Researchers are typically associated with academic or research institutions, and therefore, contribute to the knowledgebase, model development, spatial and non-spatial database development in different thematic areas of research.

5. External User

The role of the external user is mainly consulting the knowledgebase, qualitative models, outputs of analyses and maps.

The different roles that can be played by the stakeholders and their interactions with the DST are provided in Table 5:

Table 5: Stakeholders' roles and interactions with the DST software

Stakeholder	Role	System Interaction
Government agencies Central level Local level	✓ Decision maker/ planner ✓ Thematic expert ✓ Technical user ✓ Researcher ✓ External user	✓ Build model ✓ Run model ✓ Perform spatial analysis ✓ Assess alternate scenario ✓ Query map ✓ Edit data/ knowledgebase ✓ Query data/ knowledgebase
CBOs formal governance bodies resource management bodies public interest bodies	× Decision maker/ planner × Thematic expert × Technical user × Researcher ✓ External user	× Build model ✓ Run model × Edit spatial data × Perform spatial analysis × Assess alternate scenario ✓ Query map × Edit data/ knowledgebase ✓ Query data/ knowledgebase
Business organisations	× Decision maker/ planner × Thematic expert × Technical user × Researcher ✓ External user	× Build model ✓ Run model × Edit spatial data × Perform spatial analysis × Assess alternate scenario ✓ Query map × Edit data/ knowledgebase ✓ Query data/ knowledgebase
NGOs	× Decision maker/ planner ✓ Thematic expert ✓ Technical user ✓ Researcher ✓ External user	✓ Build model ✓ Run model ✓ Edit spatial data ✓ Perform spatial analysis ✓ Assess alternate scenario ✓ Query map ✓ Edit data/ knowledgebase ✓ Query data/ knowledgebase
Research and academic institutions	× Decision maker/ planner ✓ Thematic expert ✓ Technical user ✓ Researcher ✓ External user	✓ Build model ✓ Run model ✓ Edit spatial data ✓ Perform spatial analysis ✓ Assess alternate scenario ✓ Query map ✓ Edit data/ knowledgebase ✓ Query data/ knowledgebase
Cultural and religious organisations	✓ Decision maker/ planner × Thematic expert × Technical user × Researcher ✓ External user	× Build model × Run model × Edit spatial data × Perform spatial analysis × Assess alternate scenario ✓ Query map × Edit data/ knowledgebase ✓ Query data/ knowledgebase

The following use case diagram illustrates the main use cases in the Unified Modeling Language (UML):

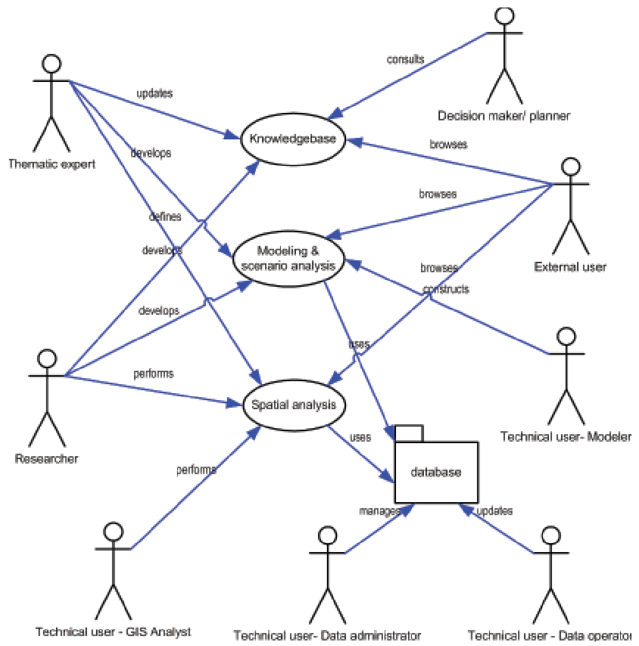

Figure 2: Main Use Cases

2.5 DST users

The possible users of overall DST were given earlier in section 2.3. Among those identified users, the ones who use DST software can be divided into following two types based on their nature of use:

- General User: The general users are those who will not be involved in advanced tasks such as modeling and advanced spatial analysis. These users will run already developed system dynamics models by changing the parameter values and policy levers of the models only. Also, these users may not have advanced GIS and modeling software at their disposal.
- Advanced User: The advanced users are those who may be involved in modeling and may perform advance spatial analysis such as researchers, modelers and managers. These users will have advanced software such as ArcGIS for spatial analysis, Simile for system dynamics modeling, etc.

The DST software was developed to provide minimum features and functionalities so that general users without any advanced software will be able to use it in their decision-making process. The advanced users will be able to use DST along with other softwares such as ArcGIS, Simile, etc.

3

System Overview

3.1 Application modules

Since the general DST users may not have commercial GIS software at their disposal, it is recommended that some form of GIS with basic GIS functionalities such as querying and viewing spatial data should be developed as a component of the DST software. Likewise, the project has used Simile software for developing system dynamics models. Therefore, the DST software should contain tools that allow viewing and running of system dynamics models using Simile, and integrating the model input and output with GIS. These requirements have lead to the development of two major application modules of DST: Spatial Analysis (SA) and Scenario Analysis, respectively.

Furthermore, the project has collected or created data, models, literatures and other information that will hold value beyond the project's lifetime. The project has developed an online metadata management system called Knowledgebase to store data and metadata of all these information and allow users to browse and search these information. However, many DST users may not have regular access to Internet and so they will not be able to access the project's online knowledgebase. This has lead to a development of offline version of Knowledgebase as an application module within DST.

The DST therefore consists of following three application modules:

- Knowledgebase
- Spatial Analysis
- Scenario Analysis

The DST software is bundled with relevant data, metadata and models and so on, developed or collected by the HKKH Partnership project so that the users can readily start using the software for their decision-making process. Furthermore, all the modules, except Knowledgebase, are flexible enough to allow users to use their own data.

The logical sequence for the operation of DST software is briefly described below (see Figure 3):

- First, the user looks at the metadata, data, reports, etc. related to his/her area of interest in the knowledgebase system using Knowledgebase module.
- Next, the user explores data (spatial and non-spatial). The user will visualise and query the spatial data using Spatial Analysis module.
- Using the Scenario Analysis module, the user will load Simile system dynamics model and assign data and/or values to model parameters. After that, the user runs the model to generate different scenarios by changing the policy levers.

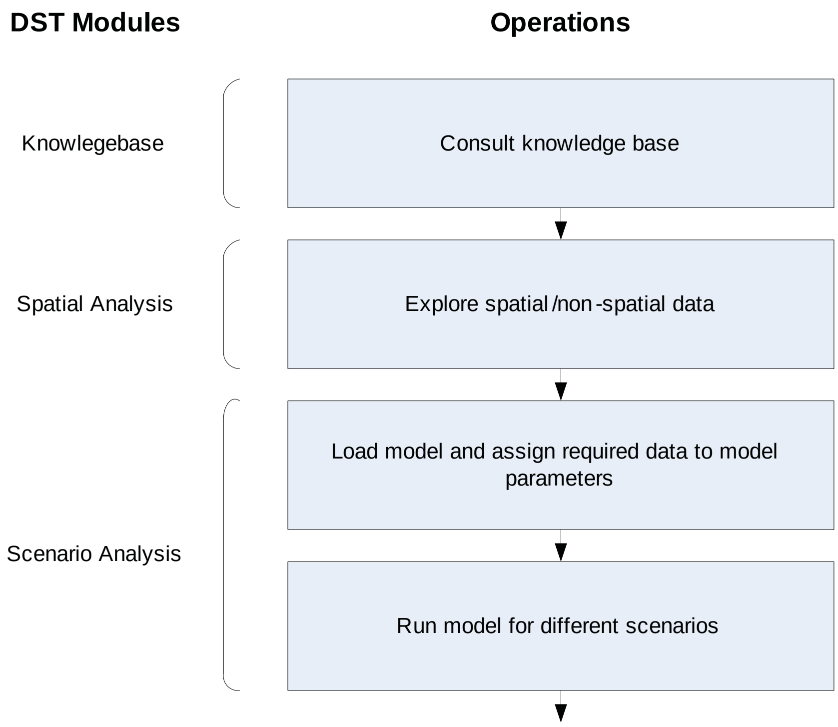

Figure 3: Logical sequence of DST operations

3.2 Data flow and processing

The different processes carried out in the DST modules, inputs and outputs of each process and flow of information are given in the following figures 4 and 5.

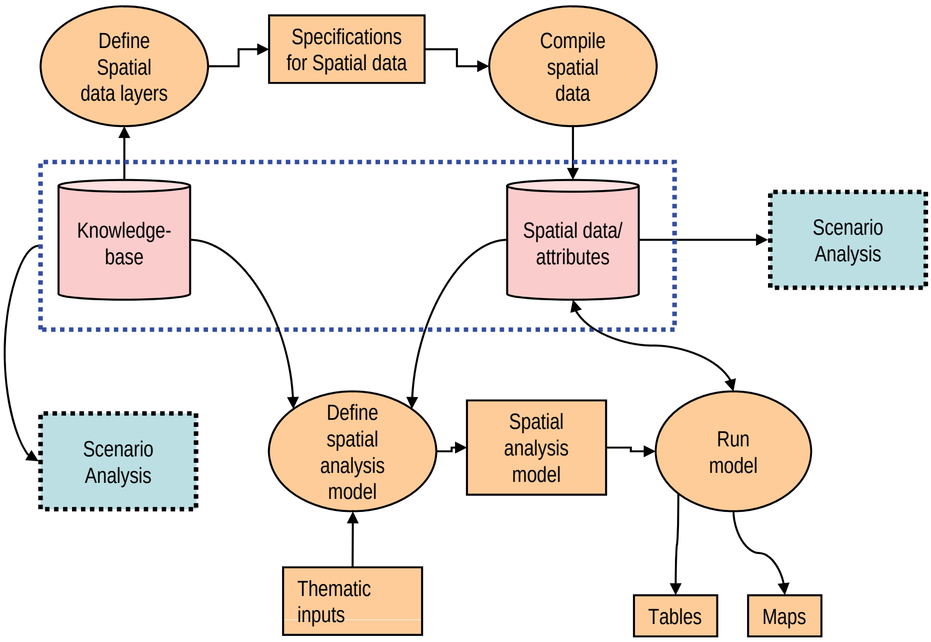

Figure 4: Spatial Analysis module

The knowledgebase, spatial and non-spatial database are core to all the modules.

In the Spatial Analysis (SA) module, spatial data layers are compiled from the spatial database based on the data requirements defined by the models. Spatial analysis and geo-processing are carried out as defined by the spatial analysis model. The model will define the processes such as buffer and overlay of spatial layers. The outputs of the analysis are stored as spatial data, and displayed as maps and tables. These output data may also be part of inputs to Scenario Analysis module.

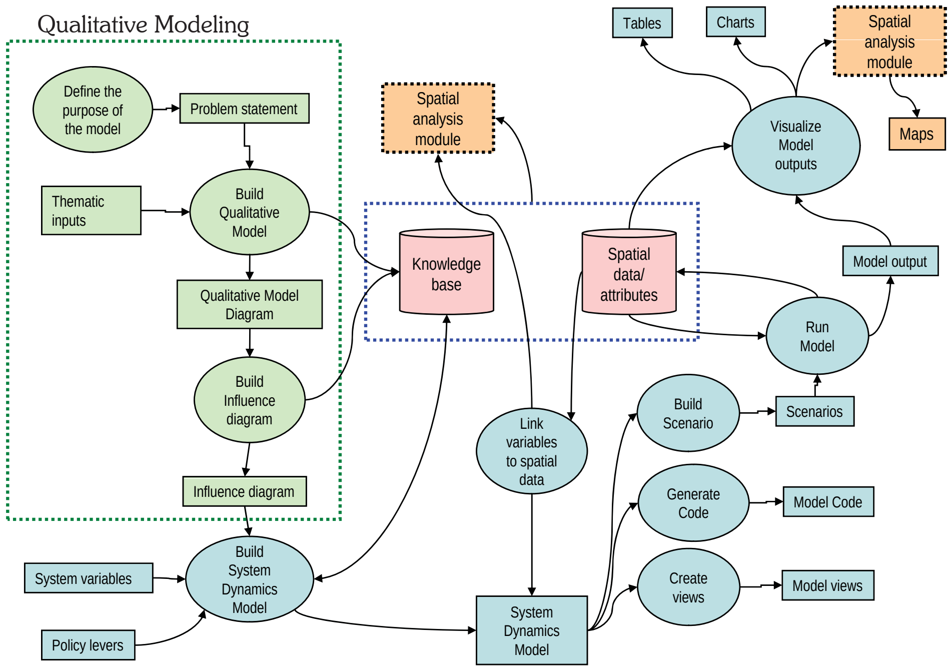

Figure 5: Scenario Analysis module

The definition of modeling requirements, development of qualitative models and influence diagrams are seen as a part of the scenario analysis. They are represented in the process diagram and are carried out by using external tools such as CMap. Based on the qualitative model diagrams and influence diagrams, system dynamics models are built in Simile. The variables for model inputs can be linked to spatial data and attribute tables as required by the model design. The model is then run to generate different scenarios. The model outputs can be visualised in the form of tables, charts and time series maps.

4

Architectural Design

4.1 Modular architecture

The DST is developed using a modular architecture. It allows the development and progressive delivery of self contained complementary modules of DST to the users. System Dynamics modeling and Spatial Analysis are considered as two important components of the DST design. Based on these, the modular architecture of DST integrates multiple technologies and applications namely—Scenario Analysis, Spatial Analysis and Knowledgebase.

Figure 6 shows the system architecture diagram of DST software. A brief description of various components of the DST is given below:

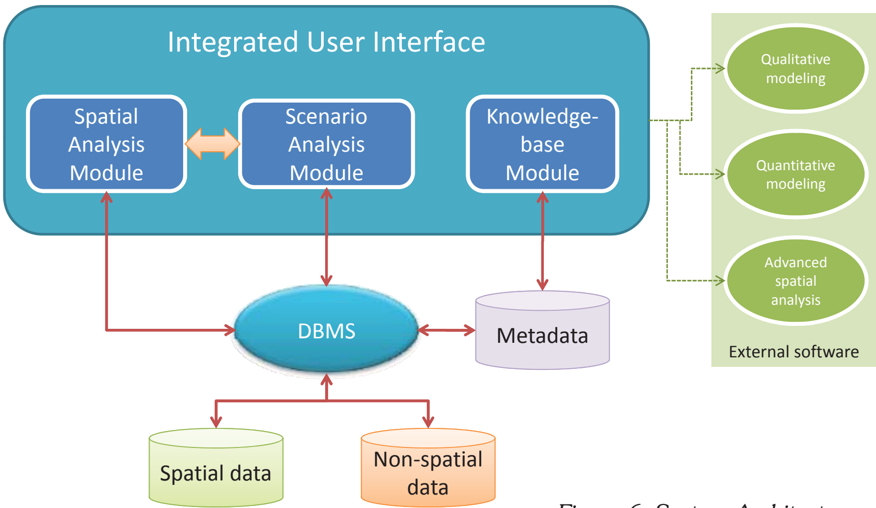

Figure 6: System Architecture

4.2 Interface

An integrated user interface has been designed for DST to provide a logical access to the different components to the users. It provides a user-friendly menu system for spatial analysis and scenario analysis modules. Menus are also provided for browsing and querying knowledgebase.

4.3 Knowledgebase module

In the context of the HKKH Partnership project, Knowledgebase has been defined as the metadata management system which allows storing the metadata of various kinds of information such as literature, spatial data, satellite imageries, models, and so on. However, this definition may not match exactly with the definition of Knowledgebase used in the general context of knowledge management and Decision Support System.

The project has implemented in its Integrated Web Portal (IWP) the Knowledgebase system using FAO's open source GeoNetwork platform. This system also allows storage of data, model or other information along with the metadata. It allows users to access these metadata by providing browsing and searching facilities.

The Knowledgebase module under DST has been developed as an offline implementation of the online Knowledgebase system and allows users to browse and search metadata just like in the online system.

4.4 Spatial Analysis module

The Spatial Analysis module provides basic GIS functions and geo-processing tools for viewing, creating, editing and analysing spatial data. The module lets the user query for spatial and attribute data and prepare maps for display and printing.

4.5 Scenario Analysis module

The Scenario Analysis module contains the following sub-modules:

- Qualitative Models (QM) sub-module
- System Dynamics Models (SDM) sub-module

Qualitative Models sub-module

The QM allows users to describe the various natural and socio-economic processes in the ecosystem making it possible to communicate among researchers, planners and decision makers to understand the activities and the results in a structured way. Further, the qualitative models form a basis for developing influence diagrams and computer-based system dynamics models. The qualitative models are developed using CMap software by domain experts. This DST sub-module offers mechanisms to browse and view the qualitative models.

System Dynamics Models sub-module

The SDM are created by transforming the qualitative models created in CMap using Simile software. The SDM sub-module allows users to run these system dynamics models and enable them to adjust model parameters and policy levers to generate different scenarios over the given time intervals. Various forms of outputs such as tables, charts, and simulations are produced in the process so that the users can analyse them and make informed decisions.

4.6 Data

Various application modules of DST use data in appropriate formats (e.g., .shp, .img by Spatial Analysis module, .csv by Scenario Analysis module, etc.).

The project has a data repository system that stores both spatial and non-spatial data in a Relational Database Management System (RDBMS) database. The advanced users of DST can access these data via Internet, using appropriate client software such as ArcCatalog for accessing spatial data. However, for the general DST users, these data are packaged along with DST software (refer to Section 8 - Data Packaging).

4.7 External software

The HKKH Partnership project has used CMapTools software to create qualitative models of SNPBZ and Simile software to develop quantitative system dynamics models from these qualitative models. A brief description of these software are given below:

CMapTools: The CMapTools software allows the creation of qualitative diagrams in the form of concept maps. The concept maps are graphical tools for organising and representing knowledge in the form of concepts and defining the relationships between them (IHMC).

Simile: Simile is a software tool developed for computer simulation of complex dynamic systems in the earth, environment and life sciences. It offers visual modeling environment that uses diagram-based language for designing models, including both system dynamics and object-based concepts. Furthermore, it uses a logic-based declarative modeling technology to represent interactions by using a complex system in a clearly structured, visually intuitive way. (Simulistics Ltd).

The DST software requires at least an evaluation version of Simile software installed in the user's machine since the SDM sub-module uses Simile Scripting facility to run the Simile system dynamics models.

The advanced users of DST who want to create their own models will need to have CMapTools for developing qualitative diagrams and licensed version of Simile for developing Simile system dynamics models. Furthermore, those users who carry out advanced spatial analysis will need to have advanced GIS software such as ArcGIS.

4.8 System development environment

The overall software development of DST has been carried out in Microsoft Visual Studio 2005 using C# programming language. C# is the most popular programming language among .NET languages where as Microsoft Visual Studio 2005 is the Microsoft's Integrated Development Environment (IDE), which lets users develop both console and graphic-user interface applications in .NET languages.

4.9 Development and deployment strategy

The DST consists of a number of application modules. These modules have been developed and delivered to users progressively, starting with simpler applications such as visualising spatial data, and gradually integrating modeling and analytical components to support systemic decision making. This approach makes it possible to smoothly build the capacity of the stakeholders while gradually institutionalising the new tools developed in various stages of project implementation.

4.10 Assumptions and dependencies

The DST has been developed for Microsoft's Windows platform. The system requirement for DST will be:

- Processor: Pentium IV or above
- RAM: 1 GB or above
- Operating System: Windows XP or above

5

Detailed System Design

This section gives detailed design specification of various DST components.

5.1 Interface

The interface of DST software is given in the Figure 7. The main features of this interface are as follows:

- It consists of vertical navigation menus that let users access various DST modules.
- The menus are collapsible in nature such that when a user clicks on a menu, it will be expanded vertically to offer users with various sub-menus and if the user clicks on it again, it will be collapsed hiding the sub-menus.
- Based on the module selected, the components of DST such as menu, toolbar and main application window are changed accordingly, providing corresponding tools and functionalities to the user.
- It allows creation of DST project file that contains the information of the data used in various application modules (e.g., GIS layers in Spatial Analysis module).

In addition to vertical navigation menus, the DST will have following three menus:

File: It consists of standard sub menus to allow users to create new DST project, open existing DST project or save the current DST project.

Windows: It consists of sub-menus to cascade or close the existing windows that are open within DST.

Help: It consists of sub-menus related to Help on DST (refer to Help section for details).

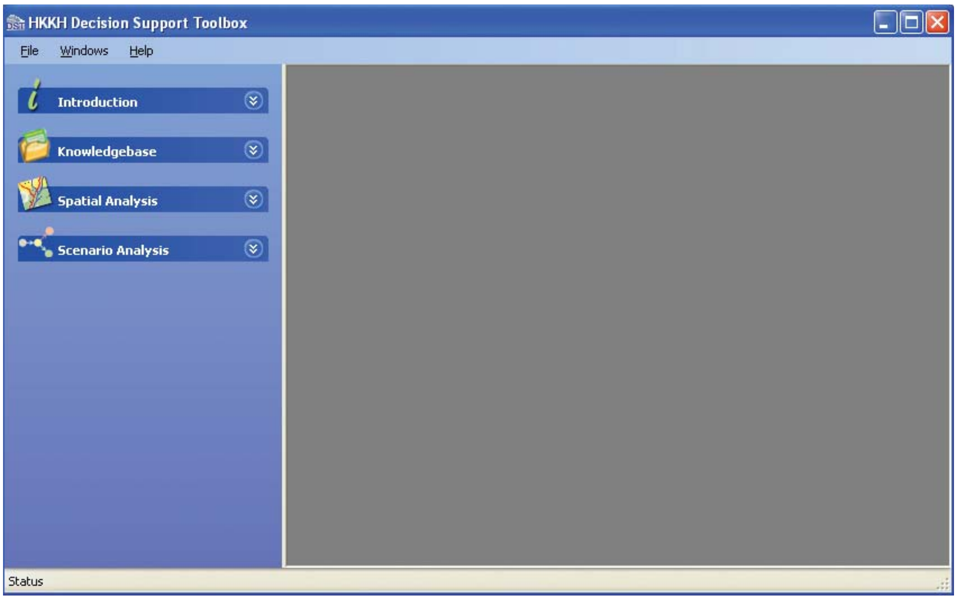

Figure 7: Prototype of DST interface

5.2 Introduction module

This module provides a brief introduction to various application modules of DST along with other information such as release version of the software, list of data packaged with the software, introductory notes on the HKKH Partnership project and so on.

5.3 Knowledgebase module

The Knowledgebase module has two components: Metadata Browse and Metadata Search.

Metadata Browse

The Metadata Browse allows users to browse the metadata of various categories such as Bibliographic Data, Maps, Spatial Data, Satellite Images and so on. The categories are listed as vertical sub-menus items under Knowledgebase menu (see Figure 8) and when a user clicks on a category, the result will be listed under the "Last results" tab.

Metadata Search

The Knowledgebase module consists of three tabs to allow users to search metadata (see Figure 8):

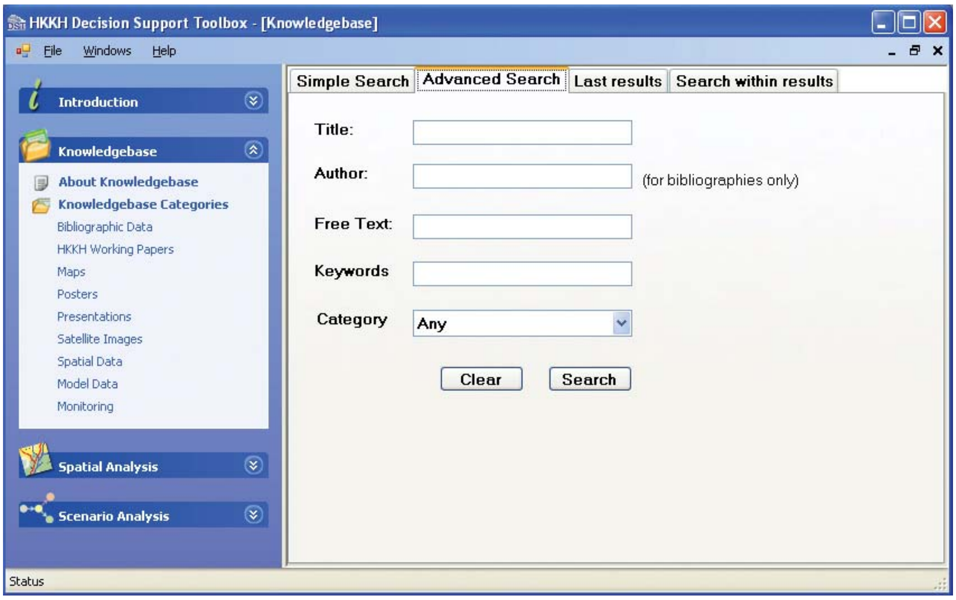

Figure 8: Knowledgebase module

Simple Search:
It allows users to search metadata by providing free text.

Advanced Search:
It lets users search for metadata based on title, author, keywords and free text. Furthermore, it allows users to select a category, such as "Bibliographic Data", "Spatial Data" and so on, to narrow down the search within the chosen category.

Search within results:
It lets users search for metadata within the previous search results.

The search results are displayed using the browser control under the "Last results" tab.

In order to display the metadata properly, suitable templates in the form of EXtensible Stylesheet Language Transformation (XSLT) files, are developed for each category. These templates are based on the XSLT templates developed for the project's online Knowledgebase system. In addition, the Knowledgebase module also allows printing of the search results.

5.4 Spatial Analysis module

The SA module offers users with basic GIS functions and geo-processing tools. The SA has been developed using MapWinGIS, an open source OCX component from the MapWindow.

Basic features of the software

The SA works with native formats of GIS (e.g., Environmental Systems Research Institute's (ESRI's) shapefile (.shp) and ERDAS Imagine (.img), etc.) without the need for converting them to special file formats. Basically, it consists of the following features:

- basic GIS query, spatial analysis in both vector and raster data.
- exporting of maps to known formats (e.g. .bmp, .jpg, .gif).
- viewing and querying the attribute table.
- adding layers to the project.
- setting the symbology of a given layer.
- creating a point feature layer from a table with coordinates information.
- creating a new feature layer by screen digitising.
- quick access to spatial data packaged with DST through its vertical menu.
- adding data table in Comma Separated Values (.csv) or dBase (.dbf) format and joining them to attribute table of a GIS feature layer based on a common field.
- an option to print at high quality with pre-defined layouts.

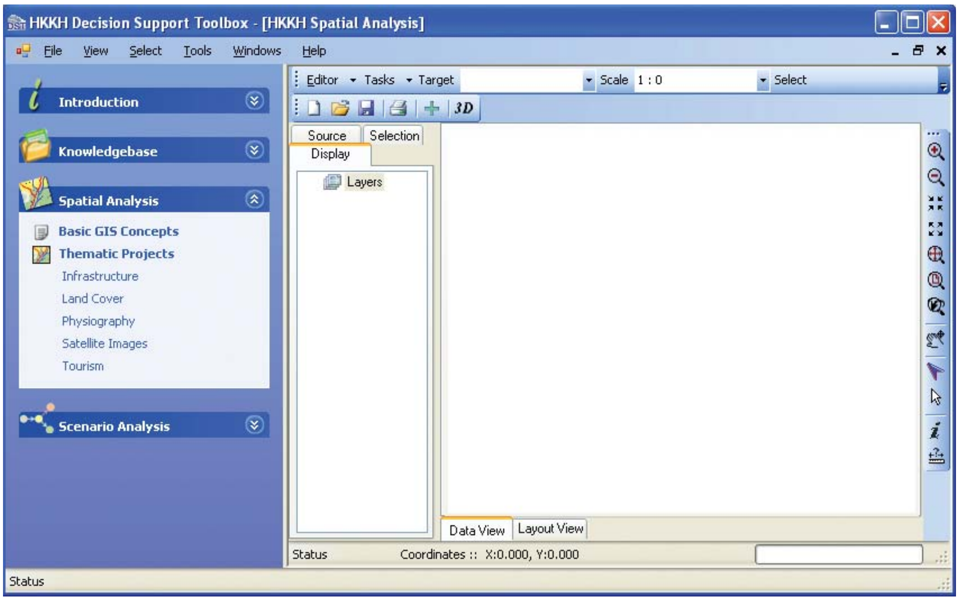

Figure 9: Spatial Analysis module

Components of SA

The SA consists of the following components:

- Menus
- Toolbars
- Layer Properties
- Attribute Table Window
- Table of contents
- Map Window

Menus

The SA consists of three main menus:

File: besides opening or creating DST project, it allows adding layers to a map, printing maps and exporting maps to common graphics file formats such as .bmp, .gif and .jpg.

Select: allows user to build a query using a Query Builder window and select the features of the given GIS layer based on the user-defined query.

View: allows users to set on and off the toolbars and table contents and also allows users to switch between a default Data View and Layout View, used for creating map.

Toolbars

The SA provides mainly two toolbars: Main Toolbar and Layer Toolbar. The Main Toolbar contains tools such as New, Open, Save, Print, Print Preview and Add Layer where as the Layer Toolbar provides a combination of menus and selection combo-boxes for carrying out spatial operations (e.g., buffering, resampling grid, etc.), setting scale of the map, setting a GIS layer for selection and so on. In addition, the SA also provides a toolbar that consists of basic GIS tools such as Zoom In, Zoom Out, Pan, Identifying tool, Hyperlink tool, etc.

Layer Properties

The SA provides dialog boxes to view and set properties such as symbology, extent, transparency levels and so on, of feature and raster layers. The Layer Properties also allows adding labels to feature layers.

Attribute Table Window

The Attribute Table Window allows viewing, selecting, querying and exporting the attributes of a given GIS layer. Also it allows adding field to or deleting field from the attribute table of the feature layer.

Table of contents

The Table of contents section of the SA consists of all the layers present in the current project and allows users to set layers visible or invisible, change the order of the layers and change the symbology of the layers.

Map Window

The Map Window is the main component of the SA module and it renders and displays the layers that are set visible in the Table of Contents.

Thematic projects

In addition to the above features and components, the SA module also contains a list of themes in the form of vertical sub-menus. When a user clicks on a thematic sub-menu, a pre-defined DST project is opened by the SA module.

5.5 Scenario Analysis module

The Scenario Analysis module contains the following two sub-modules:

- Qualitative Models (QM) sub-module
- System Dynamics Models (SDM) sub-module

Qualitative Models sub-module

The QM sub-module allows users to browse and view the qualitative models developed by researchers using CMap software. The key features of this component are as follows:

- Windows Explorer style tree navigation system to access various thematic models (see Figure 10).
- opening and viewing the models in the browser control implemented within the system.
- zooming the qualitative models using pre-defined zoom levels.
- printing the model diagrams.

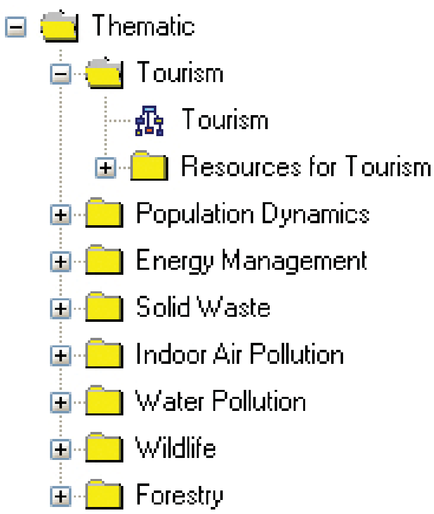

Figure 10: The Navigation System for browsing qualitative models

System Dynamics Models sub-module

This SDM sub-module allows running the Simile (.sml) model from DST environment with input and output linkage to the SA module. It uses the Simile Scripting facility for running .sml model.

The SDM sub-module allows assigning model input data from and linking model output to spatial layers present in the SA module. The operations involved under this sub-module are briefly described below (see Figure 11 for operations diagram):

Loading .sml model: it consists of loading a model such that the Simile Scripting is used to generate a Tool Command Langauge (.tcl) file along with the .csv file with a list of parameters for a .sml model.

Linking variables: it involves assigning data to the input variables of the model by providing values or linking the variables to spatial data from the SA module or from the data in user's computer.

Running .sml model: it involves running the model by specifying the policy levers and then the outputs are created in the form of table, graph or alternatively linked to spatial data in the form of attributes.

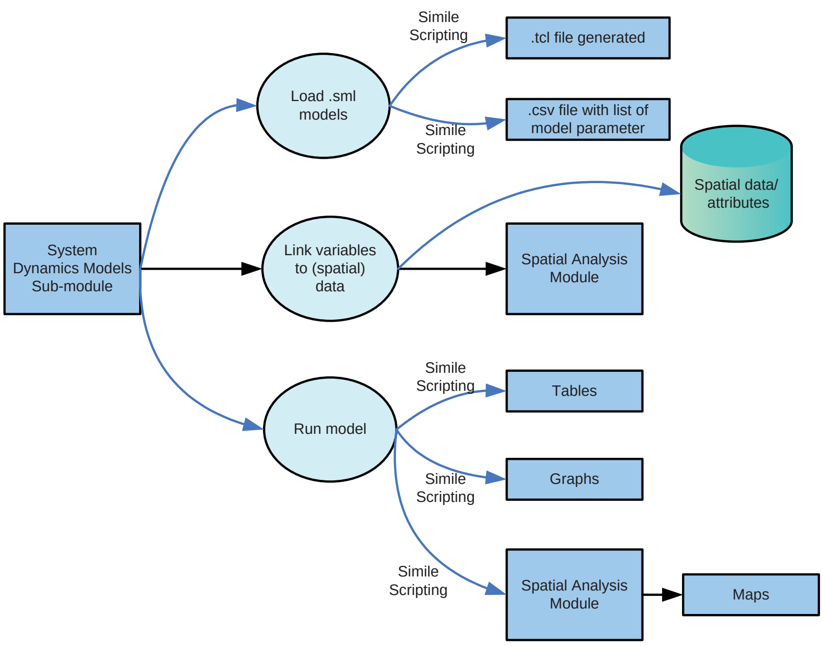

Figure 11: Operations in System Dynamics Models sub-module

The SDM sub-module provides a generic tool for running any Simile model using Simile Sripting and linking model output to GIS layer present in the SA module. As mentioned before, the HKKH Partnership project has developed a number of Simile system dynamics models (refer to System Dynamics Models section for details). The SDM sub-module provides customised tools with model-specific Graphic User Interfaces (GUIs) for these models so that users with little or no knowledge of system dynamics can also run these models easily.

All these tools mainly consist of following components:

Data Parameters:	allows assigning input data to model input variables.
Policy Levers:	allows setting the policy or management levers of the model.
GIS Link:	allows defining the link between model output and the attribute of a GIS layer present in SA module.
Run:	provides Model Runtime Environment (MRE) that allows setting the temporal parameters such as time step, display interval, number of model runs and so on, and running the model using Simile Scripting and viewing the output in the form of graphs and tables at a specified time interval.

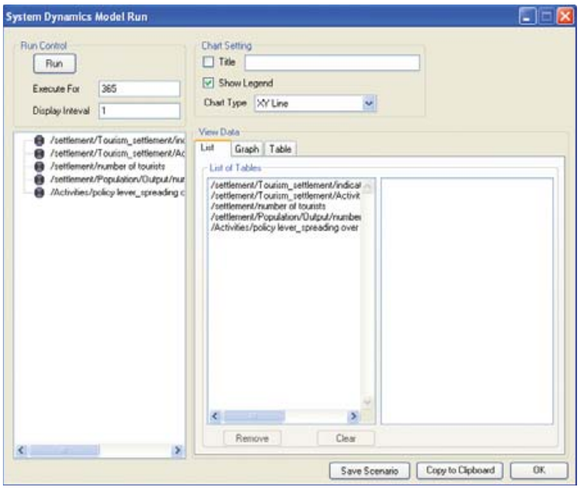

Figure 12: Model Runtime Environment (MRE)

Furthermore, the SDM sub-module joins the model output to GIS layer present in the SA module and provides Interactive Time Slider tool to visualise the temporal model output dynamically on a map.

For advanced users with ArcGIS, the functionalities existing under this sub-module are also offered in the form of ArcGIS extension.

6

System Dynamics Models

6.1 Model development process

The HKKH Partnership project has developed a number of system dynamics models to address key management problems in SNPBZ that includes issues such as tourist flow, energy use solid waste and so on. Table 6 shows the list of system dynamics models developed by the project along with their objectives as well as both the spatial and temporal scales.

The overall model development process consists of two stages. In the first stage, qualitative diagrams in the form of concept maps are prepared for each of the models by various groups consisting of modelers, researchers and domain experts. The CMapTools (IHMC) software is used to prepare these qualitative models. In the second and final stages, the CMap qualitative models are converted into quantitative system dynamics models using Simile (Simulistics Ltd.) software.

Depending upon the scope of the issues, the system dynamics models are developed at appropriate spatial and temporal scales. For example, solid waste in SNPBZ is mainly produced by tourists and locals at its various settlements and therefore solid waste model has been built to look at the monthly scenarios related to different aspects of solid-waste management.

Table 6: System Dynamics Models developed by HKKH Partnership Project

Model	Objective	Spatial Scale	Temporal Scale
Tourism	Looks at the flow of tourists and overcrowding scenario in various settlements on any given day of the year in SNPBZ.	Settlement	Daily
Population Dynamics	Analyses the dynamics of local population in the SNPBZ calculating population of given settlements on any given day of the year.	Settlement	Daily
Solid Waste	Looks at the various aspects of solid waste management including the quantification of the different types of wastes generated and the means to dispose them in an effective manner in SNPBZ.	Settlement	Monthly
Energy	Allows managers to develop an effective energy management system with the aim of balancing energy demand by supply in a sustainable manner in SNPBZ.	Settlement	Monthly
Indoor air pollution	Identifies the condition of indoor air pollution of the houses based on the types of energy sources used for cooking and heating purposes in various settlements in SNPBZ.	Settlement	Monthly
Water Pollution	Looks at the various pollutant sources such as human organic waste, solid waste, agricultural fertilisers and their influence on the biological state of the rivers in SNPBZ.	Watershed	Monthly
Forestry	Analyses the pressure on forest condition stemming from fuel wood collection, timber extraction and Non Timber Forest Products (NTFP) consumptions.	Forest	Monthly

Simile allows building a composite model containing a number of individual sub-models within one big single Simile model so that the linkage between various sub-models can be clearly defined within the model. The use of composite model allows changing the policy levers of various models and looking at the behavior of various models together. Based on the temporal resolution of the models above, the composite model has been built in two parts:

- Tourism and Population Dynamics model: This model runs on a daily basis and therefore runs for 365 days. The daily tourist and local population derived from this model are converted to monthly populations by DST that are then fed into the other composite model as input parameters.
- Solid Waste, Energy, Indoor Air Pollution, Water Pollution and Forestry model: This is a monthly composite model which runs for 12 times, once for each month of the year.

6.2 Tourism and Population Dynamics model

A Tourism and Population Dynamics model is presented here as an example of Simile model developed and integrated into DST software by HKKH Partnership project. The overcrowding has been identified as the key management problem of SNPBZ especially during two tourist peak seasons when lots of tourists go there for either trekking or climbing mountain peaks. The model (see Figure 13) analyses the tourist flow in SNPBZ and assesses the overcrowding at 18 major settlements in SNPBZ for any given day of the year.

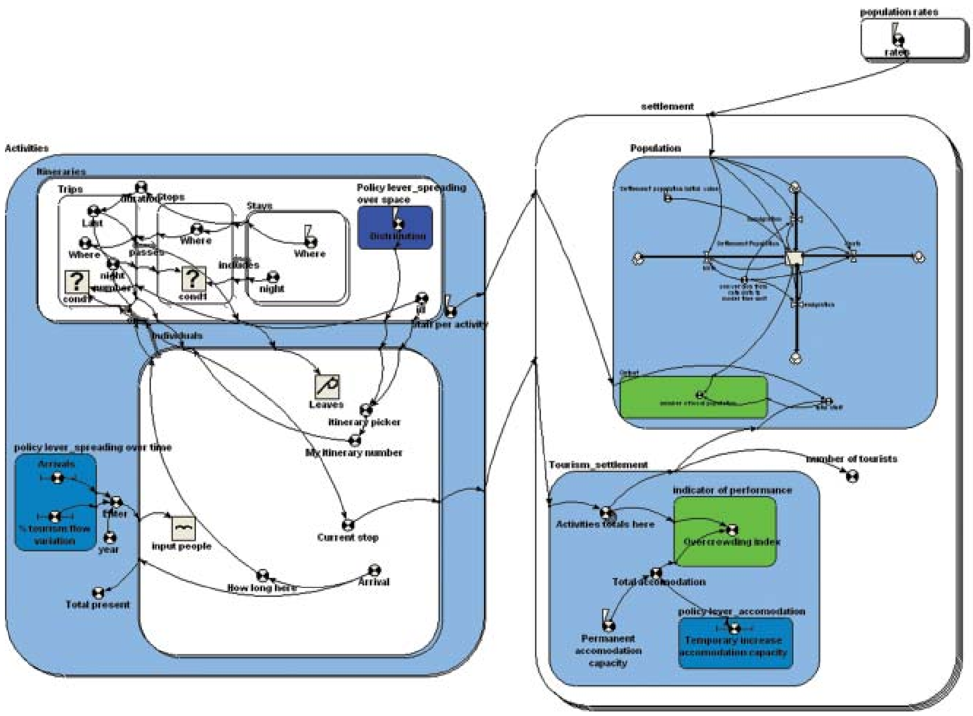

Figure 13: Tourism and Population Dynamics model

The tourism model considers two kinds of tourists, namely trekkers and climbers going to SNPBZ. Based on the two visitor surveys carried out in 2007 and 2008, the HKKH Partnership project estimated the proportion of trekkers and climbers going to 20 different itineraries such that each itinerary represents a specific route with given set of settlements where the tourists spend overnight. The tourism model uses this information along with the daily number of trekkers and climbers entering SNPBZ to estimate the number of trekkers and climbers spending overnight at various 18 settlements in SNPBZ on any given day of the year. In this model, the users can set the following three kinds of policy levers:

- Spreading visitor flows over time:
  - o % tourism flow variation: changing the percentage of tourists entering SNPBZ for the whole year and/or
  - o Changing percentage of tourists entering SNPBZ for selected weeks in a year.
- Spreading visitor flows over space:
  - o Distribution: changing the percentage of tourists (trekkers and climbers) distribution over 20 different itineraries;
- Temporary accommodation capacity:
  - o Temporary increase accommodation capacity: increasing the temporary accommodation capacity of given settlement(s).

The model gives overcrowding index as the main output and activities total, number of tourists, number of local populations and arrivals as the secondary outputs. Table 7 provides the description of all of these outputs.

Table 7: Outputs of the Tourism and Population Dynamics model

Output Variable Name	Description and Unit
Overcrowding index	The overcrowding index is calculated as the ratio of number of tourists in a settlement to total accommodation or bed capacities of that settlement. It shows a relative abundance or scarcity of bed in a given settlement with the value below 1 indicating abundance of accommodation spaces and the value above 1 indicating shortage of accommodation. [Ratio]
Activities total	Daily number of trekkers and climbers on 18 given settlements in SNPBZ. [Number]
Number of tourists	Daily number of tourists on 18 given settlements in SNPBZ. [Number]
Number of local population	Daily number of local population including porters and guides. [Number]
Arrivals	Daily trekkers and climbers entering SNPBZ. [Number]

Running Tourism and Population Dynamics model in DST

As mentioned before, the SDM sub-module of DST provides model specific GUIs for running the system dynamics model developed by the project. When a user clicks Tourism and Population menu provided within SDM sub-module, a pre-defined DST project related to Tourism and Population Dynamics model is opened by DST, which in turn adds a settlement layer along with other relevant GIS layers to SA module and also opens *Tourism and Population Model* window. The settlement layer is a point feature layer that shows the locations of 18 settlements used in the model. The *Tourism and Population Model* window on the other hand provides interfaces to allow users to view the data assigned to input variables, set policy levers, specify link between model output and the settlement layer, and finally run the model (see Figure 14).

When the user runs the model after setting the policy levers of the model, the Simile software runs the model and generates a temporary CSV output table that is used to display the result in *Table Chart* window (see Figure 15).

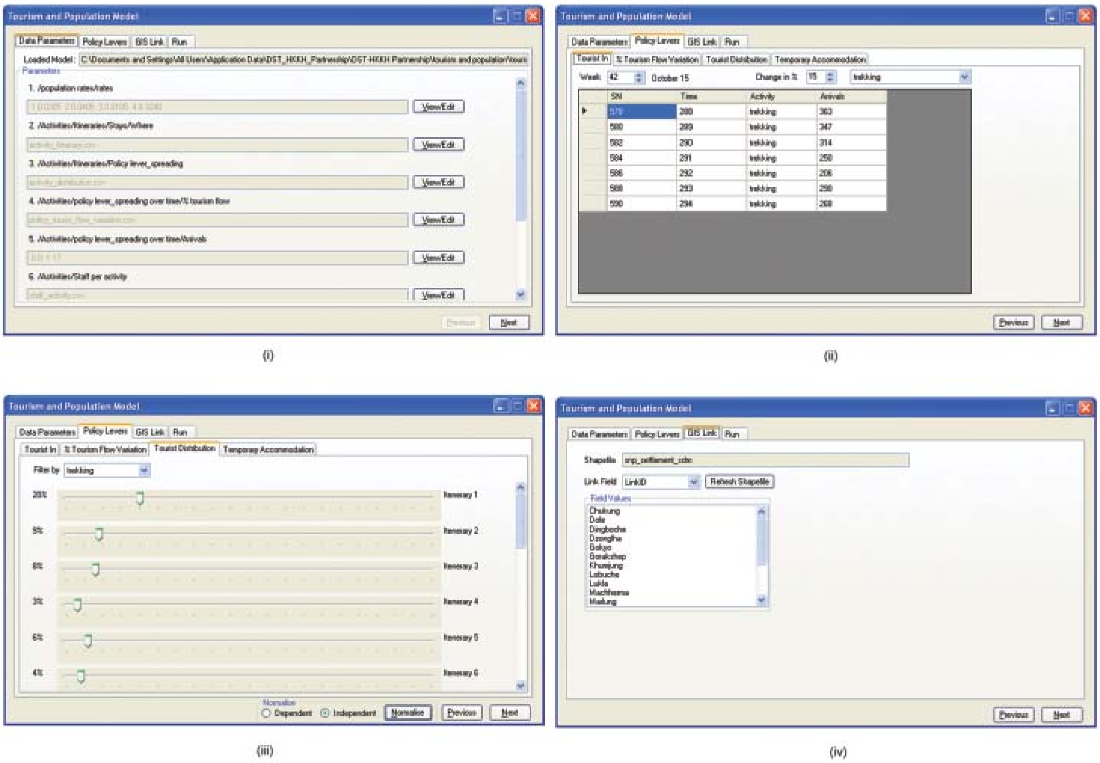

Figure 14: Examples of model specific interfaces for Tourism and Population Dynamics model:

(i) Data assigned to input parameters,
(ii) Changing % of tourist flow to SNP for selected weeks,
(iii) Changing % of tourists distribution over different itineraries,
(iv) Selecting the attribute of spatial layer for its linkage with model output table.

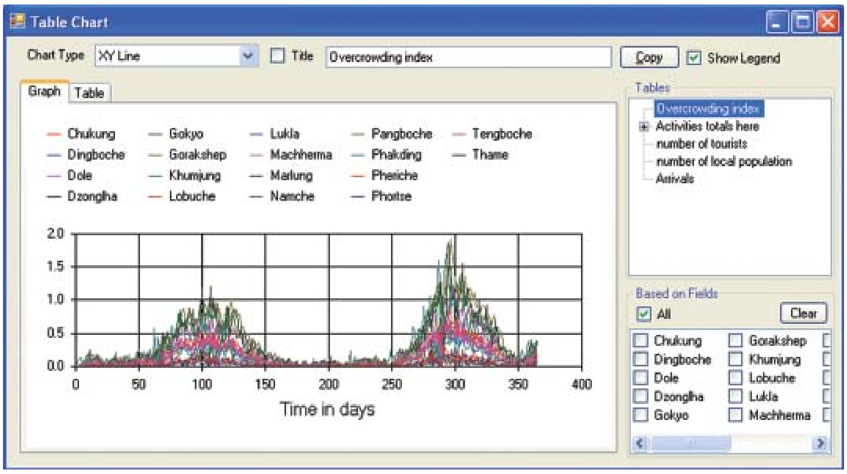

Figure 15: Table Chart window showing outputs of Tourism and Population Dynamics model

The *Table Chart* window allows users to visualise the outputs in the form of table or chart. It also allows users to link the model output to the settlement layer in SA module. By using the *Interactive Time Slider* tool, the users can view the overcrowding scenario of 18 settlements on map and chart for any given day of the year (see Figure 16).

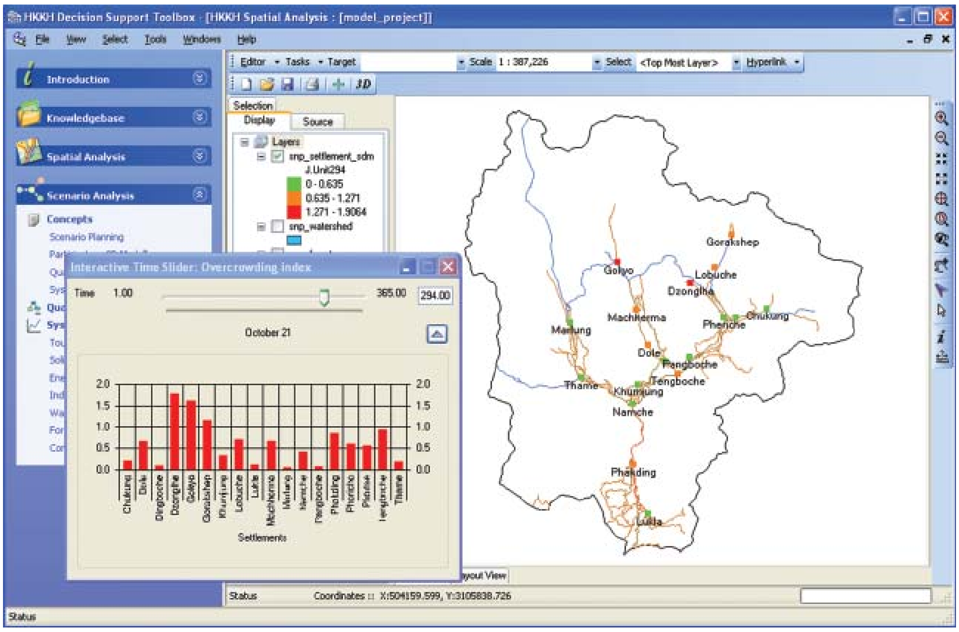

Figure 16: Dynamic visualisation of temporal model output in GIS

7

Help

7.1 Help system

A user manual on DST software has been developed to provide detailed step by step guide regarding the use of various modules of DST. Also, the software includes a standard help application that allows users to browse through help topics arranged according to major functionalities of DST and also lets users to search help on the tools of DST. The users can access both the user manual and help application using the corresponding menu items provided under Help menu in DST.

7.2 Update tool

In addition, a DST Update Tool (see Figure 17) is also provided under Help menu of DST software to allow users to update the data and other files in the user's computer. This tool decompresses the files and folders present in the DST update file, and copy them to appropriate locations thereby updating the data and models in the user's local computer.

The compressed update files will be provided periodically for downloading in the project's homepage at: http://www.hkkhpartnership.org/DST

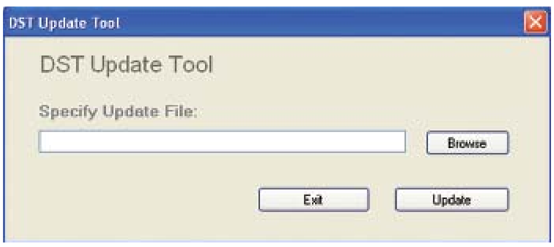

Figure 17: DST Update Tool

8

Data Packaging

8.1 Organisation of folders

The DST software provides tools that are flexible enough to handle the users' own data and models. However the data, models and other related information of a protected area, gathered or developed by the HKKH Partnership project, have also been packaged with the DST software so that they can be readily used by the DST users in their decision research process.

The data packaged with the DST software are organised in appropriate folders and sub-folders under the main root folder called HKKH DST. While organising the data, all the data related to a given module are placed within a folder corresponding to that module (see Figure 18).

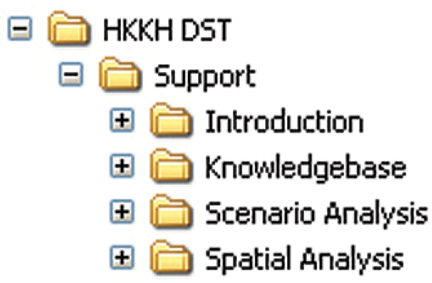

Figure 18: Data organisation

In addition, these folders also contain other relevant files and folders that are used by the corresponding application modules.

8.2 Introduction

This folder contains web pages giving a brief overview of HKKH Partnership project and introduction to various application modules of DST.

8.3 Knowledgebase

The Knowledgebase folder contains the main Metadata folder which in turn consists of all the files and folders related to Knowledgebase module arranged in various sub-folders as described below (see Figure 19):

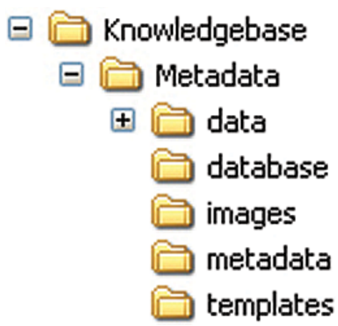

Figure 19: Knowledgebase folder structure

data:	it stores quick look pictures and downloadable files of the metadata arranged in various sub-folders.
database:	it contains an index.xml file which stores Title, Abstract, Keywords, Thumbnail, Category, etc. information of each of the metadata. The Knowledgebase module of DST uses this file for quick browsing and searching the metadata.
images:	it contains pictures used in the Knowledgebase application.
metadata:	it stores all the metadata of Knowledgebase in .xml format.
metadata Index:	it contains search index files which are used in searching the metadata.
templates:	it stores XSL style sheets which will be used to display the metadata in correct format in DST.

Packaging and updating data for offline Knowledgebase

In order to implement the offline Knowledgebase in DST, the metadata and other associated files and folders need to be copied from the project's online GeoNetwork database to appropriate location before they are packaged with DST software as described below:

- All the metadata stored in GeoNetwork database shall be exported as individual metadata XML files and placed in the metadata folder described above.
- Likewise, an index file (i.e. index.xml) containing key information of all the metadata in GeoNetwork database, shall be generated and placed in database folder.
- Search index files shall be generated and placed in metadataIndex folder to provide quick searching capability to Knowledgebase module.
- The contents of the data folder in GeoNetwork server shall be copied to data folder described above.

To automate these tasks, an application tool called **Knowledgebase Synchronisation Tool** has been developed:

Knowledgebase Synchronisation Tool

This application tool contains three tabs, each developed for carrying out specific tasks.

Export Metadata: It creates database folder within the root Metadata folder specified by the user (see Figure 20) and generates index.xml file in that folder. Also, it creates metadata folder within Metadata folder and exports all the metadata XML files to that folder.

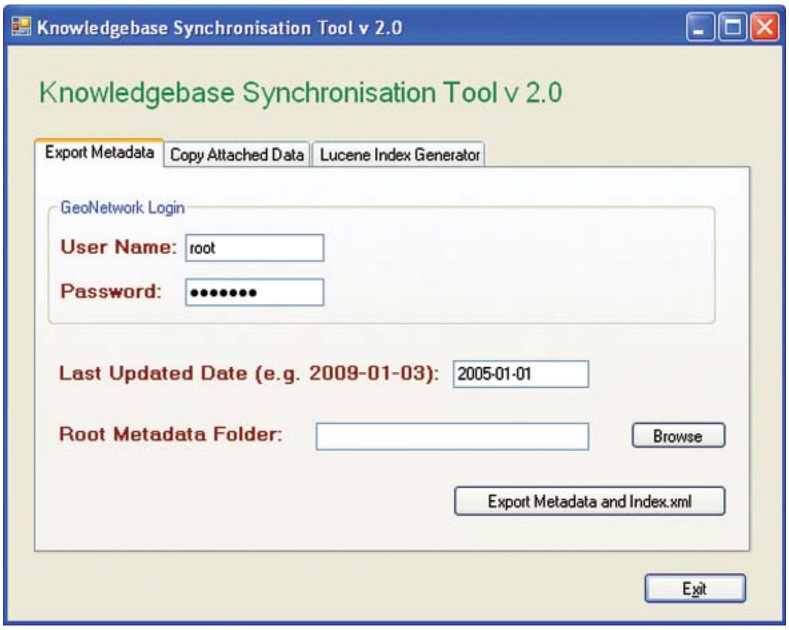

Figure 20: Screenshot of Knowledgebase Synchronisation Tool

Copy Attached Data: It copies contents of the data folder in the GeoNetwork server to data folder within user specified Metadata folder.

Lucene Index Generator: It creates search index files of all the metadata generated earlier and placed those files in metadataIndex folder within Metadata folder. An open source Lucene search engine library is used to generate these search index files. The Knowledgebase module of DST uses these search index files in its search operations.

8.4 Spatial Analysis

The HKKH Partnership project has implemented the spatial data repository system using RDBMS database. However, the spatial data are distributed to the DST users in simpler form, in ESRI's shapefile (.shp) and ERDAS Imagine (.img) formats. The spatial data packaged with DST software DVD are placed in "Spatial Data" folder under "Spatial Analysis" folder as shown in Figure 21.

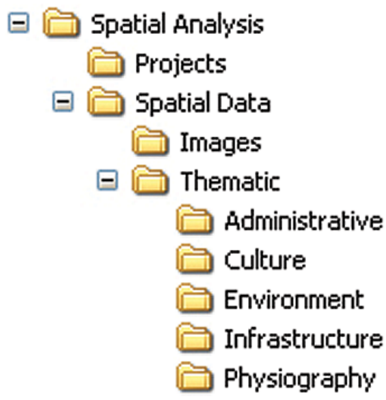

Figure 21: Spatial Analysis folder structure

The "Spatial Data" folder consists of two sub-folders:

Images:	it stores satellite images.
Thematic:	it contains thematic folders such that each thematic folder stores shapefiles and grid data belonging to that theme.

The Projects folder under "Spatial Analysis" folder contains pre-defined DST project files that allow users to quickly browse and view spatial data using Spatial Analysis module of DST. The project files are in ".dst" file format and are, in reality, the XML files.

8.5 Scenario Analysis

The Scenario Analysis folder contains two sub-folders, namely "Qualitative Models" and "System Dynamics" (see Figure 22).

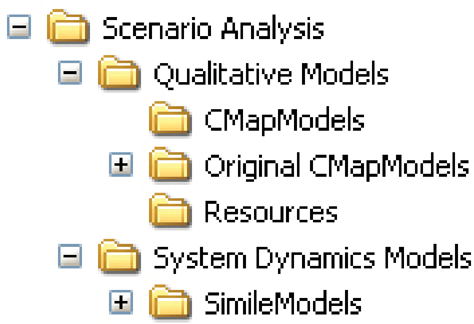

Figure 22: Scenario Analysis folder structure

Qualitative Models

The “Qualitative Models” folder stores files and folders related to qualitative models. The “Original CMapModels” sub-folder under the “Qualitative Models” folder stores original CMap qualitative models that the users can view using CMap software. Likewise, the CMap models, exported as web pages, are placed in the CMapModels sub-folder. These web pages are used to show the CMap qualitative diagrams within DST software.

System Dynamics Models

The “system dynamics models” folder contains SimileModels sub-folder which stores the Simile system dynamics models developed by the project.

9

DST Versions and Dependencies

Table 8 below shows the application modules that are included in various versions of DST along with the dependent software programs.

Table 8: DST versions and dependencies

Version	Modules Included	Dependent Software	Optional Software
beta version 1.01	Knowledgebase, Spatial Analysis	.NET Framework 2.0 DirectX	ArcGIS 9.x
beta version 2.0	Knowledgebase, Spatial Analysis, Scenario Analysis: Qualitative Models	.NET Framework 2.0, DirectX	ArcGIS 9.x, CMap, Simile
beta version 3.0	Knowledgebase, Spatial Analysis, Scenario Analysis: Qualitative Models Scenario Analysis: Systems Dynamics Models (Tourism model)	.NET Framework 2.0, DirectX, at least an evaluation version of Simile	ArcGIS 9.x, CMap, Simile
version 1.0	Knowledgebase, Spatial Analysis, Scenario Analysis: Qualitative Models Scenario Analysis: Systems Dynamics Models (all the models)	.NET Framework 2.0, DirectX, at least an evaluation version of Simile	ArcGIS 9.x, CMap, Simile

10

Testing and Debugging

Each function of DST is tested and debugged by the development team during the development process. Before releasing a new version, the DST modules are circulated among the partners for feedback. Furthermore, the DST software is tested by a number of independent testers. Based on the feedback received from testers and partners, the software is further debugged and enhanced.

11

Summary

The HKHK Partnership project has developed DST software that provides tools to support systemic planning and management of mountain protected areas and the related decision-making processes. The DST has been developed in a modular fashion such that its application modules can be used independently or in conjunction with other modules depending upon the user's requirements.

The DST provides tools to allow integration of spatial components into system dynamics modeling. In addition, it provides Interactive Time Slider which serves as an excellent tool for visualisation of temporal model output on map dynamically.

The SDM sub-module provides a generic tool that allows running of any Simile system dynamics model with input and output linkage to the GIS layers in SA module. Therefore this tool has a good potential of usability beyond the project's life. In addition to the generic tool, the SDM sub-module provides model specific interfaces for the system dynamics models developed by the project. These interfaces allow even the users with little or no knowledge about system dynamics modeling to run the models and generate scenarios that they can ultimately use in their decision-making process.

12

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IHMC [Institute for Human and Machine Cognition] - http://cmap.ihmc.us/conceptmap.html
MapWindow – http://www.mapwindow.org
Simulistics Ltd. – http://www.simulistics.com

Building partnerships for the HKKH region

The project "Institutional Consolidation for the Coordinated and the Integrated Monitoring of Natural Resources towards Sustainable Development and Environmental Conservation in the Hindu Kush-Karakoram-Himalaya Mountain Complex" (HKKH Partnership project) is a regional initiative aimed at consolidating institutional capacity for systemic planning and management of socio-ecosystems at the local, national and regional levels in the HKKH region. The project, supported by the Italian Cooperation, is implemented by International Union for Conservation of Nature (IUCN), CESVI, Ev-K2-CNR Committee and International Centre for Integrated Mountain Development (ICIMOD).

Web links:
http://www.hkkhpartnership.org
http://www.iucn.org
http://www.cesvi.org
http://www.evk2cnr.org
http://www.icimod.org