Analysis of data sharing environment and major challenges currently being faced in data sharing in Rwanda

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Abstract:

The major challenges that face Rwandan institutions for the moment in data sharing are the following: The institutions are too protective for their data and they hide data to people who are outside of their respective institutions, there is no policy for data distribution. Rwanda experiences data duplication because there is no partnership between data producers. Even if initiatives of creating NSDI are an on-going process the greatest challenge is to deal with administrative questions.

This work presents the current data sharing environment and major challenges of data sharing in Rwanda.

The author collected data during fieldwork in Rwanda at different institutions in private and government institutions using a questionnaire and other instruments such as literature review and desk studies, which have been used in this study.

A table of framework datasets and their custodians has been drowned and fill in data collected during the fieldwork done in Rwanda.

This paper explains the efforts which are ongoing in East African countries, Namibia and South Africa (eg. Kenya, Uganda and Tanzania) in building NSDI and how Rwanda can benefit from their experiences. Literature and the internet were used in the case of Canada and USA to study their NSDI structure and how it can contribute in designing data sharing workflow for Rwanda.

The results show:

- The effect of the current system of data sharing in Rwanda using a workflow;
- a table of framework datasets and their custodians in Rwanda and
- a proposed workflow model of data sharing for Rwanda.

Key words: framework datasets, Clearinghouse, spatial data, data protection, Data Sharing, Data Security, partnerships, Confidentiality, Ownership and Copyright

Abbreviations

CD: Compact Disc
CEAD: Center for Environment, Agriculture and Development
CGI: Common Gateway Interface
CGIAR-CSI: Consortium for Spatial Information
CGIS: Center for Geographic Information Systems & Remote Sensing
CGIS-NUR: Center of Geographic Information System at the National University of Rwanda
CSI: Consortium for Spatial Information
DFGFI: Dian Fossey Gorilla Fund International
EIS: Environmental Information Systems
FACAGRO: Faculty of Agriculture at NUR
FAO: Food and Agriculture Organization of the United Nations
FGDC: Federal Geographic Data Committee
FTP: File Transfer Protocol
GDI: Geographic Data Infrastructure
GEOMAPS: GEOMAPS (consultant company in GIS)
GI: Geographic Information
GPS: Global Positioning System
GSDI: Global Spatial Data Infrastructure Association
HTML: Hyper Text Makeup Language
HTTP: Hyper Text Transfer Protocol
ICT: Information, Communication and Technology
IMU: Information Mapping Unit
INS: National Institute of Statistics
ISAE: Higher Institute of Agriculture and Animal Production
ISAR: Institut des Sciences Agronomiques du Rwanda
ISAR: Institut des Sciences Agronomiques du Rwanda
ISO: International Standards Organization
ITC: International Institute for Geoinformation Science and Earth Observation (in the Netherlands)
KCC: Kigali City Council
KZN: KwaZulu Natal
LAN: Local Area Network
LIM: Land Information Management
MET: Ministry of Environment & Tourism in Namibia
MINAGRI: Ministry of Agriculture and Livestock
MINDEF: Ministry for defense
MINEDUC: Ministry of Education
MINIFRA: The Ministry of Infrastructures
MINISANTE: Ministry of Health
MINITERE: Ministry of Land, Environment, Forestry, Water and Mines
MSC: Mapping Science Committee
NGDC: National Geographical Data Committee
NGO: Non-Governmental Organization
NICI: National Information and Communication Infrastructure

NLC:	National Land Center
NMD:	National Missile Defense
NOAA:	National Oceanic and Atmospheric Administration
NRCS:	United States Natural Resources Conservation Service
NSDI:	National Spatial Data Infrastructure
NSIF	National Spatial Information Framework
NUR:	National University of Rwanda
OGC:	Open Geospatial Consortium, Inc.
ORTPN:	Rwanda Tourism Board offices
PC:	Personal Computer
PNLP:	National Program for fighting against Malaria
RDGG:	Rwanda Development Gateway Group
REMA:	Rwanda Environment Management Authority
RITA:	Rwanda Information Technology Authority
SA:	South Africa
SDI:	Spatial Data Infrastructure
SNR:	National Service of Census
SPSS:	Statistical Analysis Software
URL	Uniform Resource Locator
US:	United States (of America)
USA:	United State of America
USGS:	U.S. Geological Survey

I. INTRODUCTION

This study presents a discussion of framework data sets which are in existence in Rwanda and their Custodians; and the proposed workflow of data sharing for Rwanda. This paper highlights also challenges, opportunities, and potential steps toward the effective use of geospatial science for sustainable development

Background

In Rwanda there is a growing interest on creating a National Spatial Data infrastructure (NSDI) that makes geo-information data accessible to support governmental decision-making processes. The Rwandan government organizations have long been engaged in building and maintaining extensive collections of digital topographic mapping datasets (road network files, property and forest mapping databases).

In October 2006 a conference on SDI took place at the Intercontinental Hotel in Kigali. Different levels of government, industry and academia were present. One of the aims of the conference was the establishment and the maintenance of the national spatial data clearinghouse and to defining the policy for data distribution. The main objective of that conference was to initiate the process of the implementation of a National Spatial Data Infrastructure (NSDI) in Rwanda.

According to the Environmental Information Systems (EIS) Unit operating at the Ministry of Environment and Tourism [MET] in Namibia (2003), a National Spatial Data Infrastructure (NSDI) is a set of basic facilities and services, which embraces the following: acquisition and distribution of spatial data sets, provision of standards and regulations for the production, access, usage, costing and distribution of Geoinformation, administration and institutional arrangements, including clearinghouse, metadata, framework, geo-data and partnerships, to ensure the smooth operation of SDI (MET, 2007). For the US Federal Geographic Data Committee (FGDC, 2007) a National Spatial Data Infrastructure (NSDI) is a physical, organizational, and virtual network designed to enable the development and sharing of digital geographic information resources national wide.

It is important to understand the interrelation of different components present in the National Spatial Data Infrastructure (NSDI) like Clearinghouse, Metadata, Framework, Geo-data, Standards and Partnerships. These elements are not independent activities; they must be viewed as complementary to constructing a viable infrastructure. In NSDI, the Clearinghouse seats on the top of the layers Metadata, Framework, Geo-data, Standards and Partnerships (see figure 2.4).

1. Clearinghouse

According to CGIAR-CSI (2004) a Clearinghouse or the Spatial Data Discovery Facility (SDDF) is a web based application that allows users to discover the location and/or to download existing

spatial data. The Clearinghouses take advantage of web technology and offer tools for query, search and presentation of available spatial data.

2. Metadata:

According to Consortium for Spatial Information (CGIAR-CSI 2004) the simplest definition of metadata is “data about data”. There is a close relationship between metadata and standards. According to Steven (2004) metadata are standardized data elements that describe the data (e.g. content, quality, condition, resolution, scale, time of collection, other times it was collected, areas of coverage, ownership, and other characteristics of the actual data). Metadata permit structured search and comparison of data without having to spend the time examining the data themselves using the interface of the clearinghouse. The potential users can compare similar data collected and held by multiple organizations in one sitting and make a studied opinion as to which data best fit the user’s needs. Metadata provide the end user with adequate information to take the data and use it in an appropriate context.

3. Framework:

According to Steven (2004) a framework is the mechanism for identifying and describing the data using features, attributes and attribute values and these mechanisms are used to update the data periodically without complete recollection. Framework is also the interactions among organizations for data collection and sharing. Framework data is the set of continuous and fully integrated geospatial data that provide context and reference information for the country. Framework data are expected to be widely used and generally applicable, either underpinning or enabling most geospatial applications.

According to the GeoConnections (2006) framework data are the base layers of data or datasets that for most users agree is the base information that they will key their data, for instance: transportation, hydrology, elevation, administrative boundaries, and cadastral data. Each owner of the datasets is called a custodian.

According to the USA Department of Information Technology (2007):

- **Data Owner or Custodian**: is usually a member of senior management of an organization that is ultimately responsible for ensuring the protection and use of the organization's data.
- **Data Custodian:** is the role delegated by the data owner that has the responsibility of the maintenance and protection of the organization's data. Data Custodians are individuals or departments responsible for the storage and safeguarding of computerized information. In fact a Data Custodian may or may not be responsible for collecting the data entities.

4. Geo-data

According to Steven (2004) Geo-data are the actual geospatial data and information collected, processed, archived and potentially distributed by multiple agencies/organizations to meet disparate mission needs. It can be property ownership, political boundaries, land use/land cover, transmission lines, transportation/energy grids, geology, soils, surface and groundwater, demography, disease vectors, economic service areas, and many more. Loenen (2003) indicated that Geo-data use the framework data for reference purposes. They are not as expensive to create as framework data but their benefit is relatively few.

5. Standards:

According to Chiwozva (2006) the word standard is used in English in many different contexts. Basically a standard is a document that contains technical specifications and is used as a guideline for comparison. According to the International Organization for Standardization (ISO,2007), a standard is a document established by consensus and approved by a recognised body, which provides for common and repeated use, rules, guidelines and characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. This functionality of the standard, of providing guidelines and characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context, links the standard to metadata. In fact the metadata needs to follow or to have a standardized way of describing the data (e. g. content, quality, condition, resolution, scale, time of collection, other times it was collected, areas of coverage, ownership, and other characteristics of the actual data).

6. Partnerships:

According the US Mapping Science Committee (1993) Partnerships are cooperation, corroboration, interlinkages, coordination and consistency on efforts done by different organizations for implementing Geo-Information. In fact these partnerships reduce duplication of efforts and wages of our scarce resource and inconsistencies.
Partnerships are the glue which binds or puts together all the components of NSDI. Partnerships extend local capabilities in technology, skills, logistics, and data.

Problem statement

In Rwanda we are facing the following problems:

a) Data are scattered and not connected.

Although much data and information are available for Rwanda, they are scattered in various formats among several ministries, local agencies, research institutes and universities. There is no central repository (e. g. Nodes) or access point using website (e.g clearinghouse) for geographic data for the Rwanda.

Today, the ability and possibility to use the information is more important than just to possess it. In Rwanda there are many servers for data in different institutions. For instance at MINAGRI (Ministry of Agriculture and Livestock in Rwanda) there is a database for soil. At CGIS-NUR, the Center for Geographic Information Systems and Remote Sensing of the National University of Rwanda (NUR) has got servers for maps like forest, National Parks, etc…

At Kigali City council has got servers for Cadastral Database for Land & Revenue Management done by GEOMAPS (an international consultancy firm, based in Kenya). All these data servers are scattered around the country in different in institutions. There is no access point to these servers via internet or website/ clearinghouse in order put this information on the benefit of the public.

b) Data Duplication.

A very good example is what is happening between Kigali City Council (KCC) and CGIS-NUR. Kigali City Council (KCC) is using ArcCadastre to establish the Rwanda Cadastral Information System at Kigali City Council (KCC) and the implementation of a Geographical Information System (GIS) in Kigali City Management. Kigali City Council (KCC) is collecting data about parcels boundaries all over the town of Kigali using GPS.

CGIS-NUR, the Center for Geographic Information Systems and Remote Sensing (CGIS) of National University of Rwanda (NUR) is working at developing spatial databases and analyses at the national and regional level to provide Internet Data Distribution and Interactive Mapping capability to be useful to government decision makers, the private sector, and NGOs for their planning exercises. Kigali City Council (KCC) and CGIS-NUR are both data producers in Rwanda. Kigali City Council (KCC) and CGIS-NUR both are collecting data in Kigali but they do not have a partnership. This makes these projects to collect same data or to spend time and money on creating data which exist already in one of these projects. Rwanda experiences data duplication because there is no partnership between data producers.

c) Some data are not updated.

In the paper called Geo- ICT for Development in post-conflict areas Toward a National Spatial Data Infrastructure for Rwanda, Rutamu et al. (2006) indicated that soil database in MINAGRI (Ministry of Agriculture and Livestock in Rwanda) has been created by the National Geographic Institute of Belgium with the Service of Cartography of Rwanda in 1987 and this soil database is the one which is still in use up to now. This soil database needs to be updated because now it is almost 20 years after its creation and there are many things, which have changed like the soil degradation and the technology about soil databases.

Objectives

- To show how other countries overcome this problem of lack spatial data sharing?

- To study what are the constraints and approaches for getting valid data in a timely and affordable manner in a useful format, and how it can be shared among collaborators in Rwanda.

II. CASE STUDIES

Kate Lance (2003) gives a panoramic view of the current state of the art in SDI development highlights and diversity of SDI initiatives in Africa. This is particularly evident in the publication of an African version of the GSDI cookbook (2003) based on the efforts of GSDI (Global Spatial Data Infrastructure Association), EIS Africa (EIS: Environmental Information Systems), the UN Economic Commission for Africa and the International Institute for Geoinformation Science and Earth Observation (ITC) in the Netherlands. Lance also lists 21 national SDI initiatives that are currently under way in all parts of Africa. These include countries from both anglophone and francophone Africa. Her review also identifies some of the main problems facing SDI development in Africa.

The US National Research Council report (2002) shows that the Johannesburg World Summit on Sustainable Development in September 2002 stimulated several Africa wide studies on SDI related topics. These included a report entitled "Down to earth: geographic information for sustainable development in Africa" prepared by the Committee on the Geographic Foundation.

The republics of Kenya, Tanzania and Uganda signed the East African Cooperation treaty in 1999 thus bringing the East African Community into being and later in 2006 Rwanda and Burundi have joined this organization. This has led to a considerable increase in demand for cross border for Geoinformation (GI) exchange in the regional bloc. Infrastructure (railway and road network, airports and coastal ports), natural resources (Lake Victoria, tourists sites), telecommunication (common mobile providers and subscribers), institutions (hospitals, banks, schools and colleges), just to mention a few, are now legally and commonly shared by the citizens of the five member countries.

According to Mulaku et al. (2004) the result of this increase in cross border GI exchange has been the birth of millions of geographical data producers, vendors and users many of whom do not know about each other's data holding or data needs. The result is much more duplication of data, poor data quality control, inefficient use of the available data resources, suppression of the geoinformation market and frustrated data users.

TANZANIAN CASE

According to Richard KASUGA (2005) the SDI initiative was internalized in the Ministry of Agriculture, starting with an awareness seminar of officials and policy makers on February 20, 2004. The meeting acknowledged the need to establish agricultural SDI to be able to collate and organize huge volumes of spatial data scattered all over the country to be readily accessible to support decision-making.

The meeting recommendation was to undertake a spatial data inventory as a foundation for establishment of SDI. The objective of the inventory was to track agriculture-based spatial data to support establishment of SDI to improve agriculture production and food security in the country. The specific objectives were to raise awareness of policy makers and generators of spatial data on SDI, track available spatial data so as to avoid duplication, identify institutions for SDI collaborations and assess resources capacity implementing SDI initiatives.

The National Bureau of Statistics (NBS, 2004) in Tanzania recognizes the gainful use of Geographic Information System (GIS) and related technology in furtherance of its mission. Therefore, one of the long-term objectives of the NBS is to establish and develop a GIS. The objective has been derived by the immense recognition of the central role of GIS as an important tool for planning, decision making and implementation of sustainable development.

According to National Bureau of Statistics (NBS, 2004) each time the government decides to undertake a population and housing Census a massive pre-enumeration cartographic work has to be undertaken.
A population and housing Census involves a huge demand of both human and financial resources over a short period of time, which often becomes a burden to the government. The author thinks the use of GIS helps a lot in reducing such problems by providing an up to date and reliable geographic frame of enumeration areas that can facilitate subsequent censuses and other surveys undertaken in the country.

The report from National Bureau of Statistics (NBS, 2004) indicates that during the period under review (from 2000 to 20004), the following activities were undertaken: The preparation of thematic maps for the 2002 census district profile reports, digitization of Enumeration Area (EA) boundaries for 30 districts, digitization of ward boundaries for 60 Districts, digitization of all Regional and District boundaries, the 2002 population and housing census cartographic report is in place, a steering committee for the National Spatial Data Infrastructure (NSDI) has been formed. NSDI is setting up a technical and administrative system to provide a National Data and Information Infrastructure that will be available to a wide range of agencies and institutions. The facility creates an opportunity for data sharing in a common system.

UGANDIAN CASE

A Brief overview of SDI initiatives in Uganda shows that the national mapping activities have been going on for a long time in history but activities related to SDI have until recently been initiated by various stakeholders; for example the EFMP II (Second Economic and Financial Management Project study (EFMP II, 2000), Swede Survey Library and Information Science (LIS), Uganda Bureau of Statistics-UBOS (2004) and Access to Information Network-AEIN (2004). The EFMP II concept paper recommended a SDI with a framework and feature data exchange catalogue and with the Poverty Eradication Action Plan (PEAP) as the overarching policy framework; all these were summed and accommodated in the National Integrated Monitoring and Evaluation Strategy (NIMES).

The EFMP II study of 2001 recognizes several core components for a successful SDI like Political commitment, Legislative framework, Institutional framework for partnerships including data access policies, Technological framework including standards, Framework data sets, Wider stakeholder involvement, Educational support and Policy framework. The table 2.1 below presents Custodian and Data sets in Uganda.

Data Sets	**Custodians**
Administrative Units;	Ministry of Local Government
Protected Areas; Forest	Department/Uganda Wildlife Authority
Hydrology (lakes + rivers);	Department of Land and Surveys
Transport Infrastructure;	Ministry of Works, Transport and Communications
Manmade Structures;	Land and Surveys
Topography (elevation);	Land and Surveys Department
Aerial photographs and satellite Imagery;	Department of Land and Surveys
Land Cover (Land Use);	Forest Department
Water Points;	Directorate of Water Development
Population;	Uganda Bureau of Statistics
Health Data;	Ministry of Health
Education Data;	Ministry of Education and Sports
Land holdings/Parcels;	Department of Land and Surveys

Table 2.1: Custodian and Data sets in Uganda (Karatunga , 2002)

Kenyan case

The Government of Kenya, through its current National Development Plan 2002-2008, is implementing an initiative for the establishment of NSDI for efficient management of Geospatial Data in the country.

So far, three NSDI Workshops has been held in Kenya; November 2001, April 2002 and September 2002. Among the Recommendations of the second NSDI Workshop there was the Structure adopted for Kenya NSDI (Mbaria, 2002).

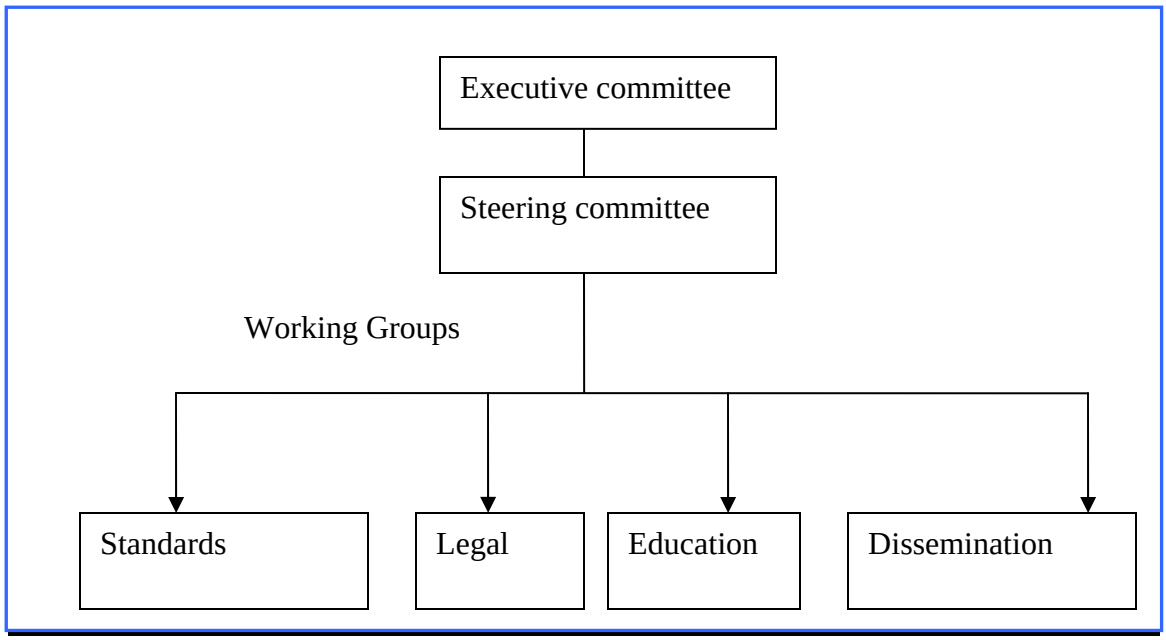

Figure 2:1: Structure adopted for Kenya NSDI (Mbaria, 2002)

According to Cesare Mbaria (2002) the figure 2.1 displays the following membership and functions of:

Executive Committee: Its membership is comprised of the director class of main stakeholders. Their function is the discussion and authorization of what is discussed in Steering Committee and Working Groups

Steering Committee: Its membership is comprised of the head of sections dealing with NSDI issues for each identified stakeholder. Their function is to assign tasks to Working Groups, to conclude tasks assigned to Working Groups and report to Executive Committee.

Working Groups (WG): are Technical Task Forces. Their members are comprised of experts in each area from each identified stakeholder.

Their function is to make recommendations on the following terms of references to the Steering Committee:

- Standards for framework data (kinds, scale etc), coding system, reference system (ellipsoid, projection), exchange format and metadata standards.
- Legal issues like copyright, liability, privacy, data policy (access, restriction, pricing, enforcement of copyright for original and secondary data, etc).
- Education includes Training, Curriculum, Research and Sensitization.
- Dissemination methods like the creation of a Clearinghouse (website) and the use of metadata for NSDI.

Comparisons of some African Countries

	NSDI Conference	NSDI structure
Tanzania	One workshop on SDI	There is no NSDI structure, but inventory of spatial data has been done.
Uganda	Two workshops on SDI	There is no NSDI structure, but inventory of spatial data has been done and a table of framework datasets and their custodians is available.
Kenya	Three workshops on NSDI	Yes They have got NSDI structure. It has been adopted at the second workshop of NSDI in Kenya.

Table 2.2: comparison of initiatives about NSDI in Tanzania, Uganda and Kenya

The table 2.2 indicates that three NSDI Workshops have been held in Kenya; November 2001, April 2002 and September 2002. At the second NSDI Workshop there was the Structure adopted for Kenya NSDI (Mbaria, 2002).

In Uganda activities related to SDI have been the use of GIS in economic and financial management, in statistics and access to information Network and in poverty eradication. The inventory of spatial data has been done and a table (see Table 2.1) of framework datasets and their custodians is available and it is considered as a foundation for establishment of SDI. According to GSDI (2006) the first Workshop on development of a Spatial Data Infrastructure in Uganda which was held on the 7th June 2006 at the Makerere University in Uganda. It was recognized that Geo-information can play a key role in development but its management in Uganda is limited by lack of an operational National Spatial Data Infrastructure (NSDI). The second workshop on SDI was organized by the ITC's research group on SDI Technology (2007) in September under the title "Design Methods for sustainable SDI 2007" in Kampala in Uganda.

The table 2.2 shows that in Tanzania an inventory of spatial data has been done. According to Richard KASUGA (2005) a workshop took place in February 20, 2004 in Tanzania and some of the outcomes were acknowledged of the need to establish agricultural SDI to be able to collate and organize huge volumes of spatial data scattered all over the country to be readily accessible to support decision-making. The objective of the inventory was to track agricultural based spatial data to support establishment of SDI to improve agriculture production and food security in the country.

The comparison of initiatives about NSDI which have been undertaken by Tanzania, Uganda and Kenya shows that Kenya is ahead compared to Uganda and Tanzania because it has already organized and held three workshops on NSDI; and the structure of NSDI is available.

NAMIBIAN CASE

According to Ministry of Environment & Tourism (MET, 2003) in Namibia, the Namibian draft policy for NSDI presents the following components:

- The Environmental Information Systems (EIS) Unit in the MET (Ministry of Environment & Tourism);
- The NSDI-Committee;
- The NSDI Technical Team;
- Users inside and outside of Government Institutions

The figure 2.2: shows how user requests can be handled.

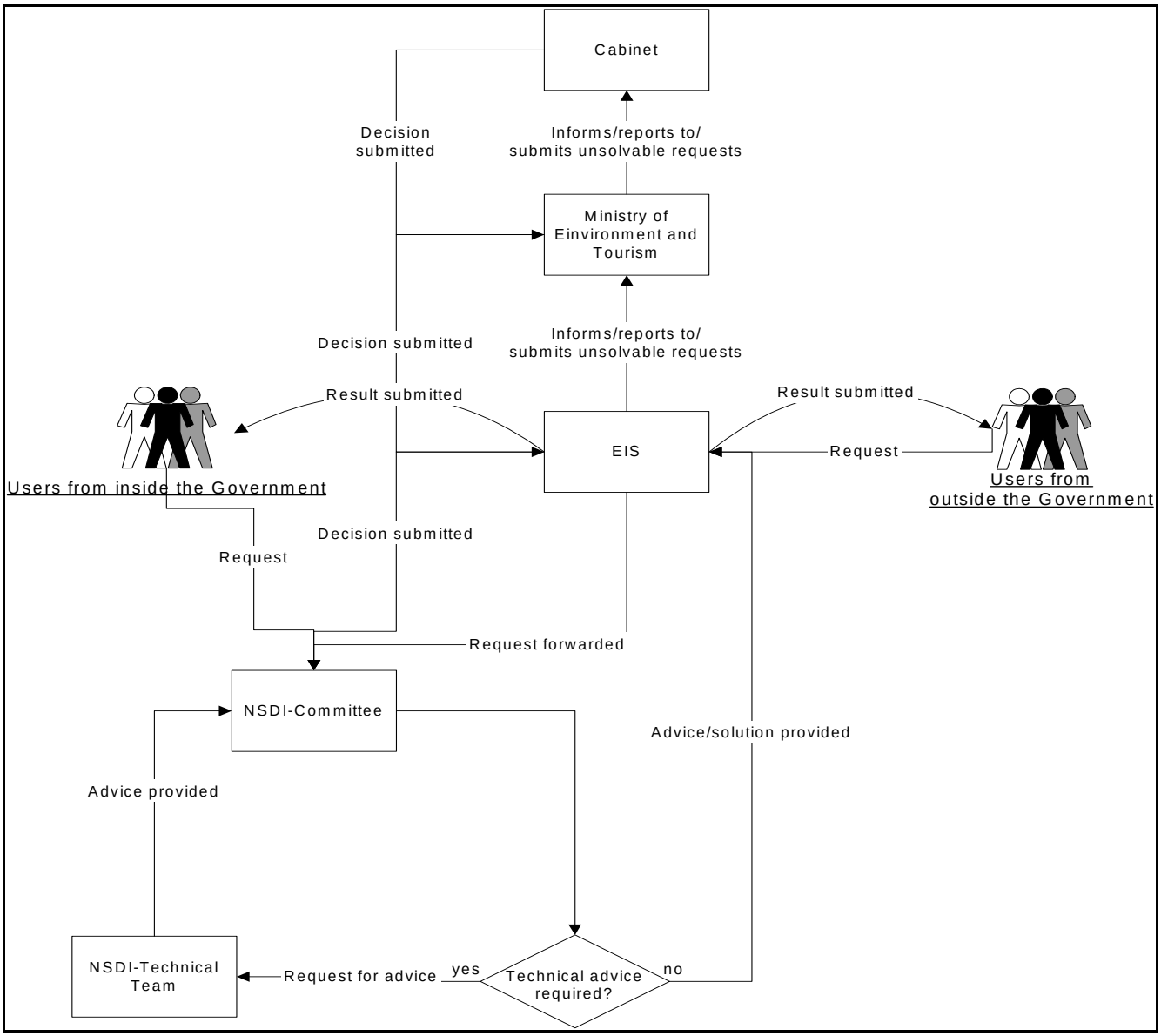

Figure 2.2: The suggested workflow of handling user requests (MET, 2003)

The figure 2.2 displays the workflow of handling user requests from inside and outside of the government in connection with the distribution and availability of spatial data.
Members of the NSDI-Committee are at middle management level with basic knowledge about topics related to spatial data. The members of the NSDI-Committee serves as the contact person in the specific Ministry regarding any issues related to spatial data infrastructure. It is suggested that each Ministry implements an internal committee in order to discuss spatial data matters. The member of the NSDI-Committee shall bring those matters then to the attention of the NSDI-Committee (MET, 2003).

The Environmental Information Systems (EIS) and MET

The figure 2.2 presents the workflow of NSDI and how the Environmental Information Systems (EIS) Unit in MET (Ministry of Environment & Tourism) provides logistical and technical supporting services for the implementation of the NSDI. Furthermore, the Unit assigns personnel and infrastructure necessary to fulfill these duties. EIS will serve as the contact institution for any kind of requirements from users outside the Governmental Institutions. The management of MET serves as the liaison body to the Cabinet in order to regularly update Cabinet about ongoing activities and developments as well as to seek advice from Cabinet to resolve issues which can't be solved internally (MET, 2003).

NSDI-Committee

The NSDI-Committee is the overseeing and decision-making body. The members of the NSDI-Committee are nominated by each Ministry to serve on a two-year term. This committee should agree on a chairperson for that period of time and meets once every three months or on demand in case of an urgent matter. The decision of the urgency of a matter lies with the EIS Unit and the chairperson of the committee (MET, 2003).

NSDI Technical Team

The NSDI Technical Team consists of five persons that will assist the NSDI-Committee by providing technical advice and support in the scope of the decision making process. For the same period as the NSDI-Committee, each Ministry will nominate any number of persons as members for the Technical Team. Members of the NSDI-Committee will select the people forming the technical team at the beginning of each two-year period. The members of the Technical Team should have comprehensive technical knowledge in the fields of spatial data production, sharing, maintenance and management.

Users inside and outside of Government Institutions

Therefore, requests, queries and concerns from users inside the Governmental Institutions are submitted to the NSDI-Committee via the representative of the specific Ministry. Requests from users outside the Governmental Institutions should be submitted via the EIS to the NSDI-Committee.

These legal issues and the workflow of data sharing tackled before by Namibia can be used by Rwanda as a comparison before the implementation of its own policy on NSDI and data sharing.

SOUTH AFRICAN CASE

In South Africa, the NSIF (National Spatial Information Framework) is fulfilling the same role as the GeoConnections (Canada) and the FGDC (USA.). The NSIF (2007) has been established by the department of Land Affairs in South Africa in 1997 in order co-ordinate the development of infrastructure needed to support the utilization of spatial information and create a single central database and to make it possible to link different databases, which are maintained by agencies, using common standards and protocols.

However in South Africa they do not have an equivalent to the NSDI (USA) or the CGDI (Canada).

USA CASE

According to USA National Research Council's Mapping Science Committee in their report on “Toward a coordinated spatial data infrastructure for the nation” the term spatial data infrastructure (SDI) was coined in 1993 by the US National Research Council to describe, amongst other things, the provision of standardized of Geographic Information (GI) access. Although FGDC defines SDI cogently, Williamson et al. (2003) argue that the SDI concept continues to evolve as it becomes a core infrastructure supporting economic development, environmental management and social stability in developed and developing countries alike.

The USA Federal Geographic Data Committee (FGDC) in 1994 approved a first version of a content standard for metadata, the Content Standard for Digital Geospatial Metadata (CSDGM). The Executive Order 12906 signed by President Clinton in 1994, "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure," requires all Federal agencies to use the CSDGM standard to document data that they produce beginning as of January 1995 (US FGDC, 2004).

A report from US FGDC (2004) indicates that in June 1998, the FGDC endorses the second version of the FGDC Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998). At the present time all the US federal agencies that produce geospatial data are required to use the CSDGM standard. This standard is complex, but it provides a common framework for agencies to build detailed metadata upon. State and local agencies have been encouraged to adopt this metadata standard to help support the National Spatial Data Infrastructure (NSDI). Metadata which follow the Content Standards are machine-readable so that they can be searched and parsed on distributed NSDI Clearinghouses.

USA National Spatial Data Clearinghouse design (US FGDC, 2004) (see figure 2.3)

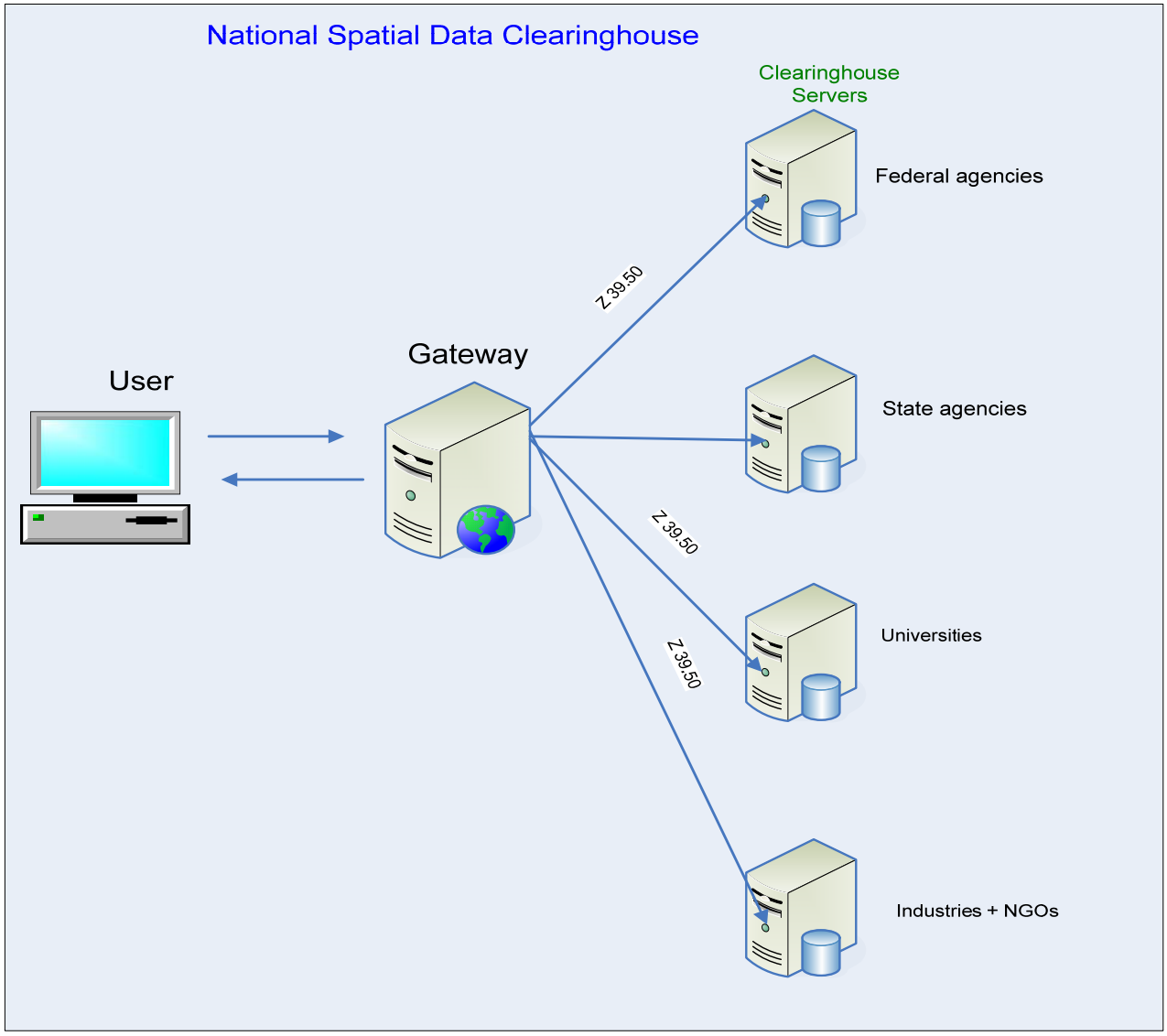

Figure 2.3: Example of USA National Spatial Data Clearinghouse design (US FGDC, 2004)

According to US FGDC (2004) the US National Spatial Data Clearinghouse is comprised of the following components (see figure 2.3):

- **User**

The web server generates web (HTML) pages that are sent to the clients (stand alone PCs) where the web browsers (e. g. Internet Explorer) interpret and display (present) the application (US FGDC, 2004).

- **Gateway**

Gateway consists of the web server. A web server is a computer connected to the Internet that stores and distributes Web pages upon request (Elms College, 2007). In fact this computer holds physically the Web site on its hard disk and transfers web pages and information over the Internet as they are requested using one or more protocols, such as HTTP, FTP, and so on. In actual fact the term refers to software (Apache) running on that computer allowing Web pages to be requested and then sent to a user's Web browser (US FGDC, 2004).

- **Clearinghouse servers**

There are many database servers distributed all over USA like federal agencies, state agencies, universities, industries and NGOs. They are managed and maintained by their individual owners (or data vendors). These databases must all conform to a common standard (the Z39.5 protocol). The metadata describe the actual data, where they can be found, in what format they are, and so on. In some cases the metadata might contain links to the actual data (if these are available online). These links can include URL's, e- mail addresses and telephone numbers. The format of the actual data varies from HTML web pages to satellite images and microfiche archives. Some of the actual data are free and some of them can be bought from the data vendor. (US FGDC, 2004)

Two protocols which have been used:

- **HTTP**

HTTP is the set of rules for exchanging files between the web browser and web sever. The web relies on HTTP as the main glue to link the web client and web server. HTTP functions as a message carrier. It carries user requests from browsers to servers and takes the requested information (graphic image, text, sound, video, and other multimedia files) from servers back to browsers (Zhong-Ren, 2003).

- **Z 39.50**

According to National Information Standards Organization (NISO), an American National Standards Institute (ANSI) (2007) the ANSI/NISO Z39.50 defines a standard way for two computers to communicate for the purpose of information retrieval. In fact the ANSI/NISO Z39.50 search protocol is a computer-to-computer communications protocol designed to support searching and retrieval of information, full-text documents, bibliographic data, images and multimedia in a distributed network environment.

CANADIAN CASE

Canada's challenge is to create an infrastructure of geospatial data to allow businesses better access to geospatial information for more effective decision-making and greater productivity. According to Groot and McLaughlin (2000) Geospatial Data Infrastructure (GDI) encompasses the networked geospatial databases and data handling facilities, the complex of institutional, organizational, technological, human, and economic resources which interact with one another and underpin the design, implementation and maintenance of mechanisms facilitating the sharing, access to, and responsible use of geospatial data at an affordable cost for a specific application domain or enterprise.

According to GeoConnections (2004) the Canadian Geospatial Data Infrastructure (CGDI) provides Canadians with common-window access to geospatial services and information through the Internet. It harmonizes Canada's geospatial information into easily accessible and searchable databases. Canadian Geospatial Data Infrastructure (CGDI) is fulfilling a similar role as the NSDI in USA.

According to Groot & McLaughlin (2000) Geospatial Data Infrastructure (GDI) “includes networked geospatial databases and data handling facilities, which interact with one another to facilitate the sharing, access to and responsible use of geospatial data at an affordable cost”.

The figure 2.4 shows how data and information are exchanged by different institutions like ministries, Agriculture institutions, utilities, Cities, Security/Emergency, Engineering, and Transportation. Using Geo-data, the NSDI enables the whole country to be Interconnected/Networked and makes easy the flow of information and data; and avoiding duplication of data.

Geo-data (see figure 2.4)

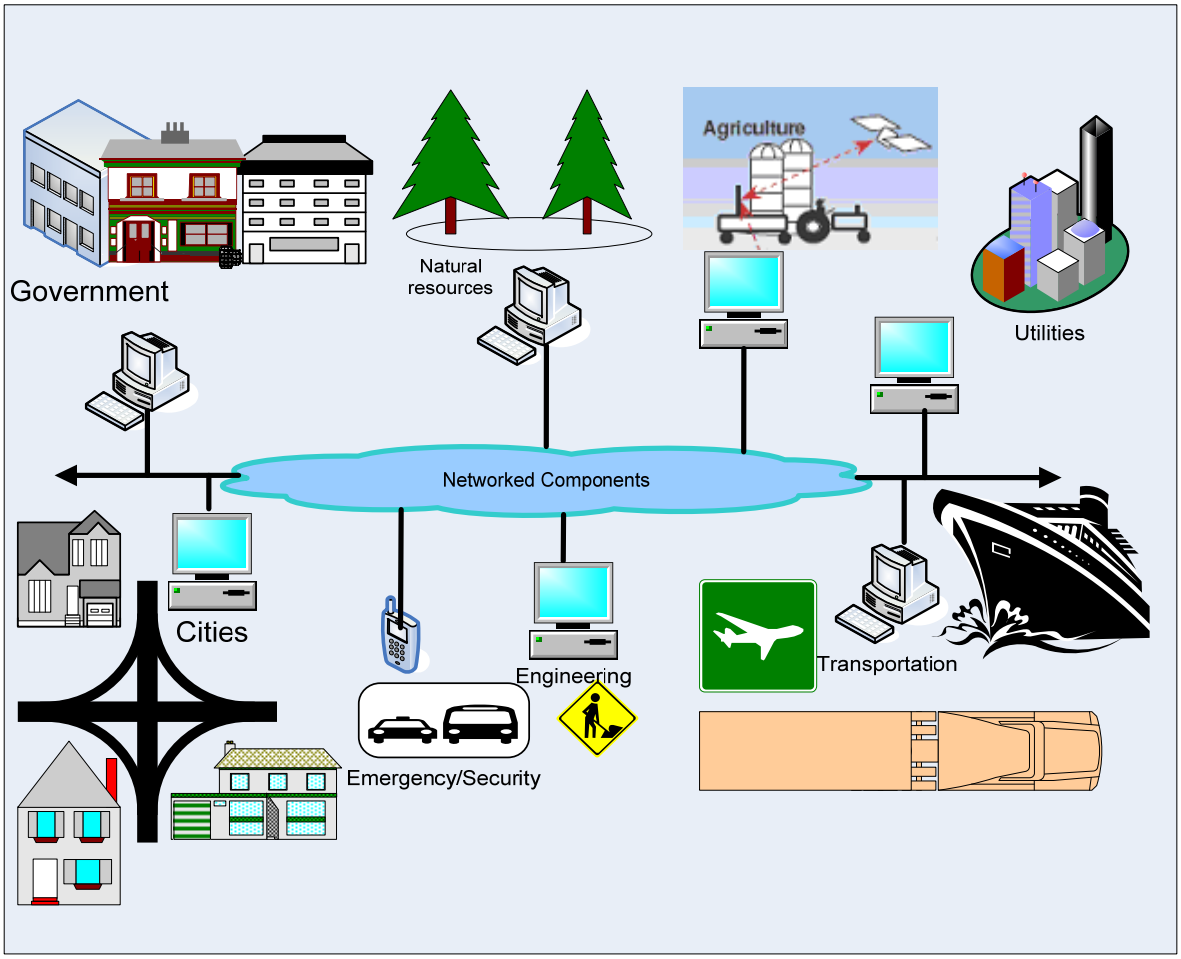

Figure 2.4: Geo-data (CEAD_LIM, 2006)

GeoConnections works with partners in public health, public safety and security, the environment and sustainable development, aboriginal matters, and geomatics technology development. GeoConnections helps decision-makers to use online location-based or geospatial information, such as maps and satellite images. GeoConnections (2004) enables federal, provincial and territorial governments, along with the private and academic sectors, to work together to build the CGDI, ensuring fast, consistent and harmonized access to geospatial information and services for all Canadians. GeoConnections is fulfilling a similar role as the FGDC in USA.

The figure 2.5 shows GDI approach designed by Groot and McLaughlin (1999) which is use in municipalities in Canada.

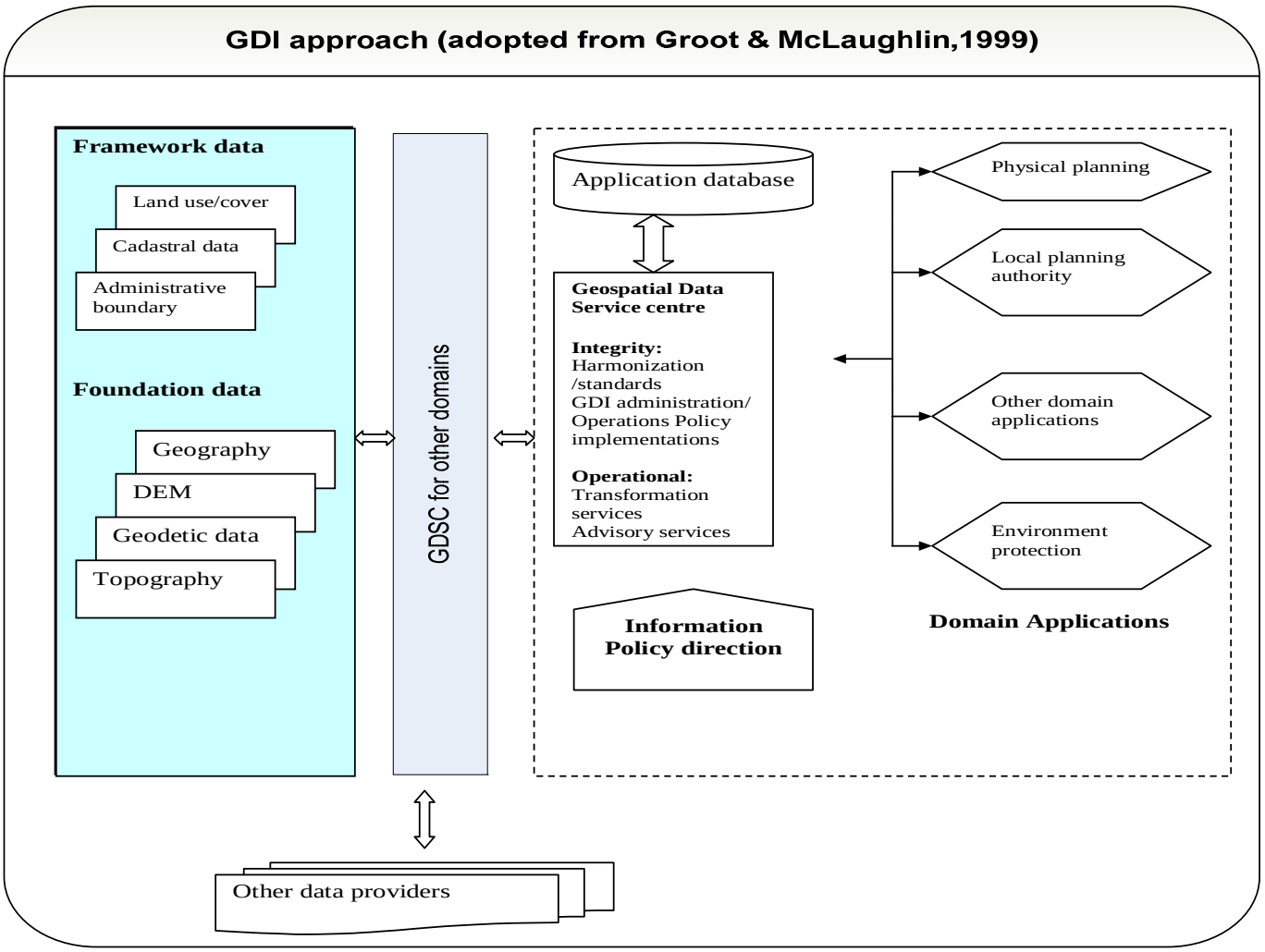

Figure 2.5: GDI approach (Groot and McLaughlin, 1999)

On the left hand side of the figure 2.5 are framework data like land use/ land cover, cadastral data and administrative boundaries. According to GeoConnections (2007), framework Data lie at the heart of the Canadian Geospatial Data Infrastructure (CGDI) and are the set of continuous and fully integrated geospatial data that provide context and reference information for the country. GeoConnections (2007) define the framework data as the bedrock of the Canadian Geospatial Data Infrastructure (CGDI) and indicate that CGDI has being built through GeoConnections partnerships.

Fundamental data like geography, the Digital Elevation Model (DEM), which has been produced by the Canadian Forestry Service in Ontario region, the geodetic, topography are represented at the left side on figure above.

On the right hand side the figure 2.5 of GDI approach, there are the individual applications within the domain with their GIS systems, which all need routine supply of directly applicable data. This stream of requirements is being met through a Geospatial Data Service Centre (GDSC). The GSDC harmonises or standardises all data for its application domain. It ensures that they are (national) metadata standard to facilitate the sharing of the resources in the domain and amongst other potential users.

Comparison of the USA and CANADIAN NSDI

The basic driving forces behind all three national spatial data infrastructures (for USA and Canada) are more or less the same: i.e. good governance, promoting economic growth and sustainable resource management. All two NSDIs also have more or less the same components.

However, there are marked differences in the mechanisms that have been developed for coordination in the two countries. The composition of the US Federal Geographic Data Committee (FGDC) is broad in scope but restricted nevertheless to federal government agencies. So far the US Federal Government has not acted upon this recommendation of the US National Academy of Public Administration to establish a broadly representative National Spatial Data Council to complement the FGDC in providing national leadership and coordination for the NSDI.

GeoConnections (Canada), on the other hand, is essentially a cooperative organisation that seeks to bring together all levels of government, the private sector and academia.

A report from Geographic Information Network in Europe (GINIE, 2002) summarized some of the main findings of the study in figure 2.6.

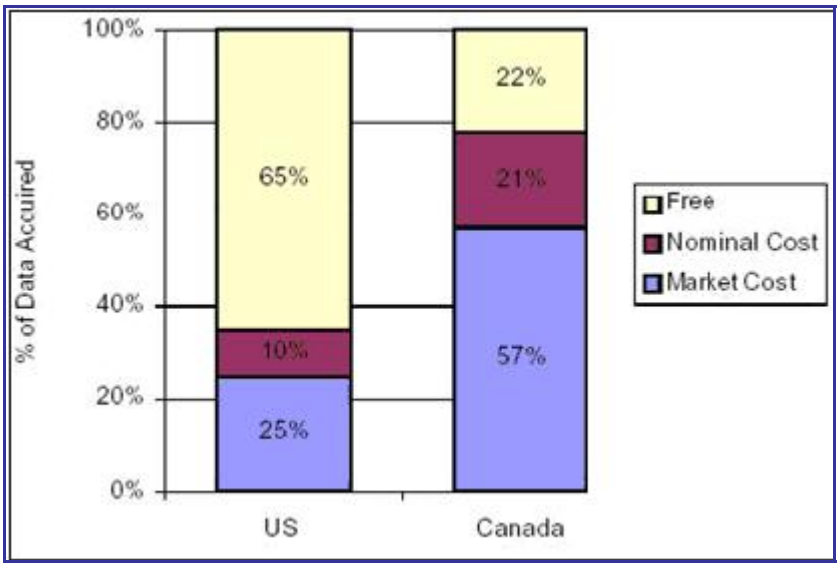

Figure 2.6: A comparison of the volume of data used by cost (GINIE, 2002)

From the figure 2.6 it can be seen that two thirds of the data provided by American data producers is free whereas over half of data are being sold at market cost in Canada.

The author considers it a major strength for the SDI of a country that it enables a diverse group of users to access a wide range of geo referenced data sets like it is the case for USA.

III. CHALLENGES AND APPROACHEES FOR GETTING DATA

The above section discusses challenges and approaches for getting valid data in a timely and affordable manner in a useful format, and how it can be shared among collaborators in Rwanda.

a) Analysis of the Current situation of data sharing in Rwanda

The author has observed during fieldwork that the current methods of data sharing in use in Rwanda are CDs (Compact disc) and Flash disc (FD) for all the institutions in Rwanda. The private and government institutions do not have in their websites spatial data which can be downloaded via internet.

Workflow of the current system of data sharing in Rwanda

Government institutions:

- ⇒ User inside the government institutions uses CD or FD to share data within this institution.
- ⇒ User Outside the government institutions uses CD or FD to get data from this institution.

Private institutions:

- ⇒ User inside the private institutions uses CD or FD to share data within this institution.
- ⇒ User Outside the private institutions uses CD or FD to get data from this institution

Government institutions and Private institutions: Government and Private institutions exchange data between them using CD and FD (see figure 3.1)

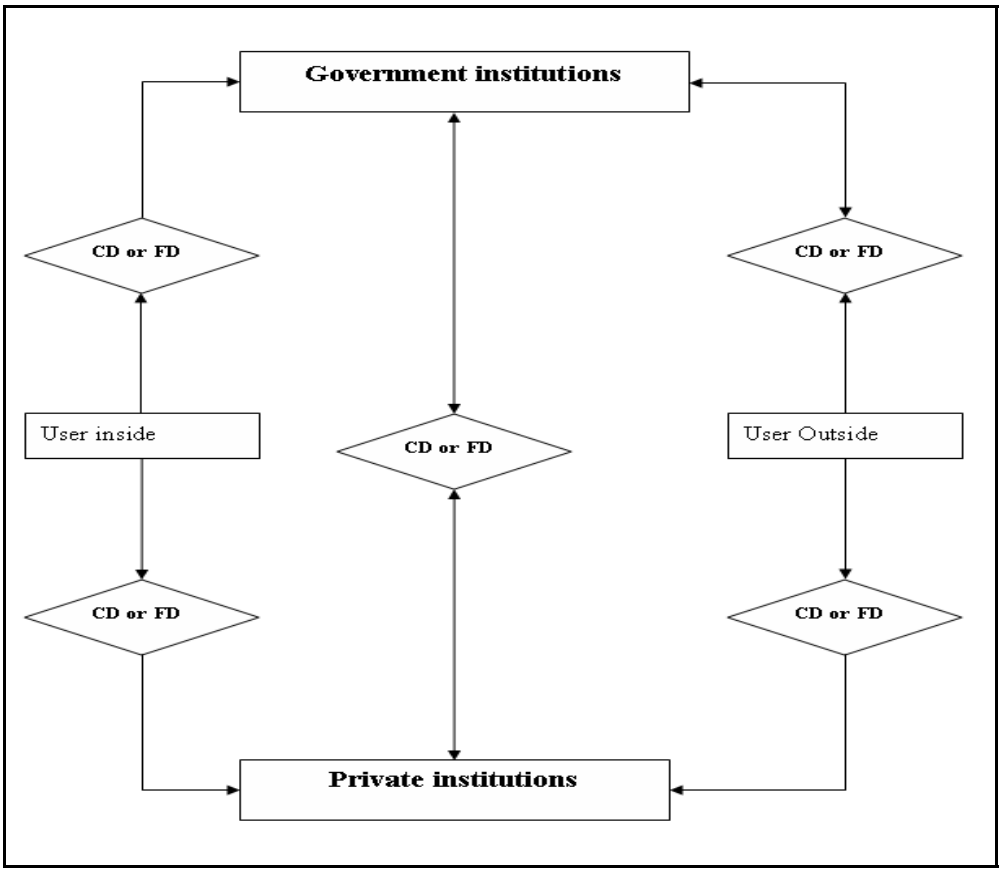

Figure 3.1: workflow of the current system of data sharing in Rwanda

Discussion

The major challenges that Rwandan institutions face for the moment in data sharing are the following:

- Even if initiatives of creating NSDI are an on-going process the greatest challenge is to deal with administrative questions.
- The institutions are too protective for their data and they hide data to people who are outside of their respective institutions;
- There is no policy for data distribution.
- There is no partnership between data producers
- The workflow of the current system of data sharing in Rwanda (see figure 3.1) consumes much time and money for a researcher in order to get data. This system is not fast compare to where a user has a possibility to download data from the internet on a clearinghouse.

- **To determine which Framework data sets are in existence in Rwanda and its Custodians**

Table 3.1 shows the framework data sets in Rwanda and its Custodians as have been collected during field work. The information in this table was collected using the following tools: questionnaire, desk study, literature review, and internet (i. e. Websites)

Custodians (departments responsible)	Feature	data sets	Attribute
Ministry of Agriculture and Animals Resources	**Agriculture**	Soils, vegetation and cattle	Dominant soils, Biomes and Vegetation types
Ministry of Local Government, Good Governance, Rural Development and Social Affairs.	**Administrative Boundaries**	National Boundary	Name of the country
		Province Boundaries	Name of the provinces
		District Boundaries	Name of the districts
		National Park Boundaries	Name of the park
Ministry of Land, Environment, Forestry, Water and Mines.	**Environment**	Temperature	Low, Average, Maximum annual temperatures
		Rainfall	Variation in annual rainfall
		Evaporation	
		Wind	Frequencies of wind from different directions
Ministry of Land, Environment, Forestry, Water and Mines.	**Land**	Geology	Major rock formation and sequences
		Land usage	Type of land use
		Mines	Name of mines, type, status
		Land Cover	Category of Land Cover
		Land ownership	Categories of land ownership
		Land control	Categories of control over land
		Conservation	Areas allocated and proposed for conservation
		Land forms	Category of land forms
Ministry of Infrastructures	**Infrastructures**	Power Lines	Number of power lines
		Telecommunication lines	Number of telecommunication lines
		Roads	Name of roads, type of road
		Air Strips	Name of the air strips
		Towns	Name of the towns
Ministry of Health	**Malaria and HIV**	Malaria infection	Rates of infection by malaria and malaria zone/area
		HIV infection	HIV infection rates
Ministry of Education	**Education**	Education facilities (for primary, secondary	Number and distribution of education facilities

		schools and universities)	
SNR (National Service of Census) National Bureau Of Statistics	**Demography/population**	Population distribution	Densities of people in all Rwandan provinces
		Population density	Number of people per km2
		Population in urban and rural areas	Urban and rural populations in Rwandan provinces
Ministry of Defense	**Topography**	Elevation	mountains, valleys, and the shapes of landforms
Ministry of Land, Environment, Forestry, Water and Mines.	**Water Features**	Lakes	Name of the lakes
		Rivers	Name of the rivers
		Dams	Name of the dams
		Surface Water Supply scheme	Name of the scheme, capacity of the scheme

Table 3.1: Framework data sets in Rwanda and its Custodians

Discussion

The author thinks that the spatial data inventory in Rwanda can be a starting point for the establishment of SDI. The objective of this inventory was to track all the basic spatial data to support the establishment of SDI in the country. The specific objectives were to raise the awareness of policy makers and producers of spatial data on SDI, track available spatial data in order to avoid duplication, identify institutions for SDI collaborations and assess resources capacity for implementing SDI initiatives.

b) The proposed workflow of data sharing for Rwanda

The proposed workflow of data sharing (see figure 3.2 below) shows the paths and systems used in the linked flow of activities. The figure below shows where inputs are initiated, the location of decision points and the alternatives in output paths.

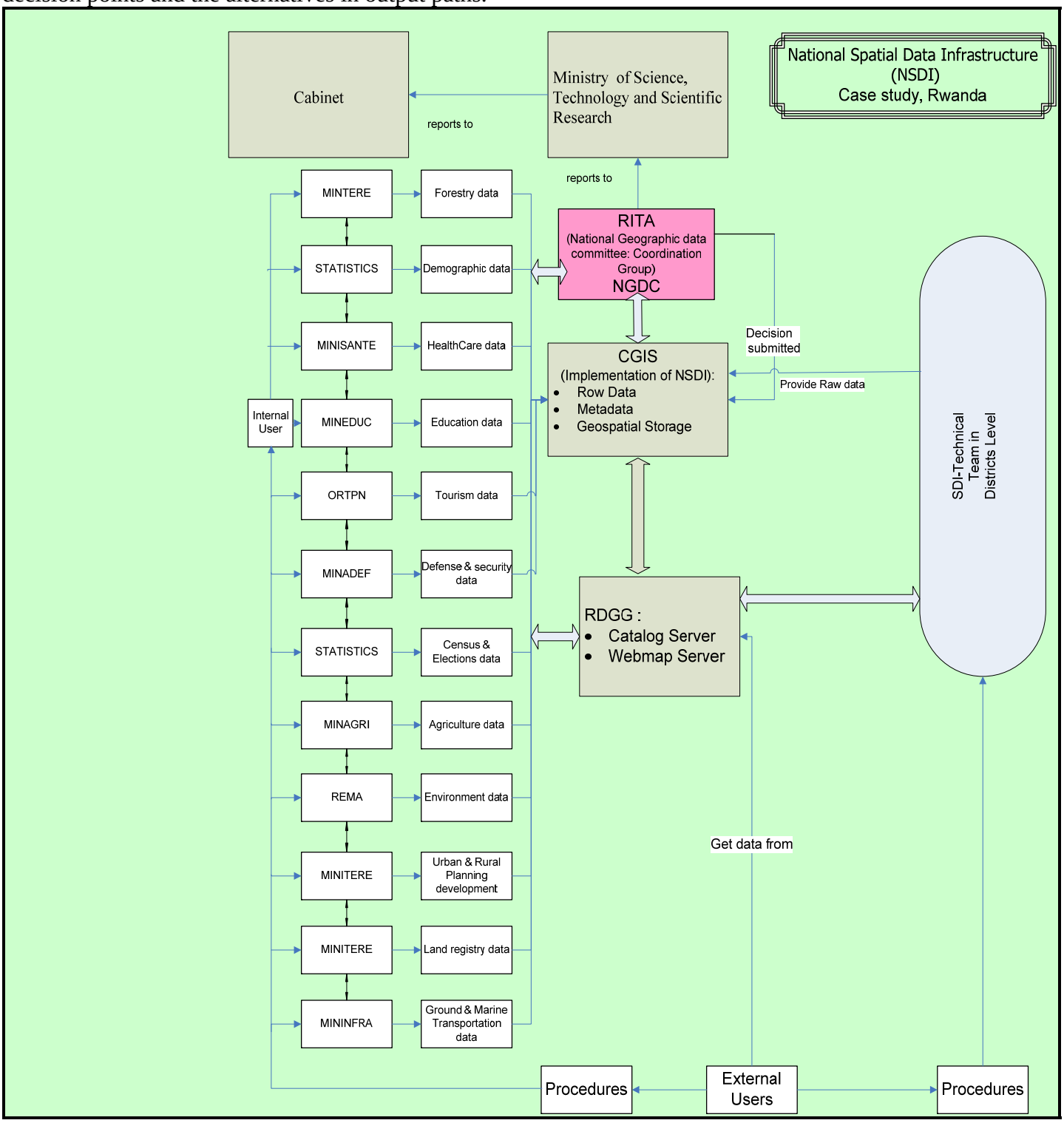

Figure 3.2: proposed workflow of data sharing

The figure 3.2 presents the proposed workflow of data sharing.

The stockholders in Rwanda in the above workflow figure 3.2 and the proposed role in data sharing are as follows:

- **Ministry of Science, Technology and Scientific Research**

  This ministry would be informed about the progress of NSDI by RITA through the NGDC (National Geographic data committee).
  This ministry informs the government/cabinte about progress of NSDI development in Rwanda.

- **Sharing of spatial data between different governmental Institutions (eg. MINITERE, MINAGRI, ORTPN, REMA, MINEDIC etc…) would follow procedures (see the figure 3.2).**

- **Rwanda Information Technology Authority (RITA):**

This institution (RITA) exists already in Rwanda and It has been designed in order to serve as the national coordinating body to support the development and the implementation of the National Information and Communications Infrastructure (NICI Plan). RITA operates autonomously, with linkages to the IT Divisions/Directorates of the Ministries as well as with other ICT-related organizations in the public and private sector in Rwanda. RITA also has the responsibility for developing National ICT Standards and Guidelines and has the ICT Consultancy role as well as public awareness and education role in the area of information and communications technologies. (RITA, 2007).

From the above background, RITA appears to be the best institution in Rwanda to support and join all the institutions in Rwanda into NSDI. The creation of the National Geographic data committee (NGDC) into RITA will help to coordinate activities of NSDI.

The NGDC is formed to promote the development and implementation of the National Spatial Data Infrastructure (NSDI). The NGDC will address institutional barriers, identify and develop policy changes, identify most effective ways to collect, maintain and distribute data, designate data stewards, reach consensus on framework, encourage metadata creation, clearinghouse development, encourage the use common standards and, participation in national and international standards committees, seek new partners, develop incentives for participants etc…

- **The Center for Geographic Information Systems and Remote Sensing (CGIS & RS)**

  The CGIS can play different roles like Implementation of NSDI, producer of spatial data, Metadata, Geospatial Storage and update and maintenance the clearinghouse.

- **Rwanda Development Gateway (RDGG)**

Rwanda Development Gateway (RDGG) is a project of the Government of Rwanda run under the National University of Rwanda (NUR).
RDG can hosting Severs like Catalog Server and Webmap Servers in order to exchange and use information systems and techniques and accessible via the web for NSDI.

- **SDI-Technical Teams**

Creation of SDI-Technical Team at district level.

A SDI-Technical Team is a collaborative process for a District to organize the way it produces, archives, and shares its geospatial assets. The SDI-Technical Team address institutional barriers, identify most effective ways to collect, maintain and distribute data, designate data stewards, as best we can to fit into NSDI recommendations (including, metadata creation, Clearinghouse development, Framework, Etc). SDI-Technical Team develops Enterprise Plans (I-Plans) for data production and publication by the most appropriate partner(s) at accuracy and scale(s) needed by local and district jurisdictions. The SDI at district level helps all levels of government fulfill their missions, develop links between the NSDI and the District and its data, Supports and facilitates: The NSDI in concept and operation of GSDI from local to global.

- **External Users**

These users outside the government institutions and need to follow procedures in order to have access to data

- **Internal users**

These users are working into government institutions and they have got much more access to data and they participate into creation of raw data.

c) Ongoing process of the Implementation of the Portal in Rwanda

According to CGIS&RS (2006) Conference on Spatial Data Infrastructure in October 2006 organized by the CGIS-NUR in collaboration with the National Institute of statistics in Rwanda (NISR) and Centre for Geographic Information System and Remote Sensing of the National University of Rwanda In collaboration with the National Institute of Statistics, President Office and HIDA (the Human Resources and Institutional Capacity Development Agency) had the following goals: to develop an awareness of SDI in Rwanda, to encourage the collection, processing, archiving, integration, and sharing of geospatial data and information using common standards and interoperable systems and techniques and accessible via the web by, to discussing SDI implementation policies and institutional aspects (legal framework, information policy, education, financial aspect), to discussing SDI implementation technological aspects (clearinghouse, metadata, standard, Geo-ICT infrastructure, internet and network connectivity) and how a SDI framework , metadata system and clearinghouse could be implemented in Rwanda. After this conference on SDI of 2006 in Rwanda, some of actions related to SDI took place as a follow up for instance the SDI-Training on “GIS Portal Toolkit” in August 2007 with participants from the President Office, RITA and the CGIS&RS-NUR and the objectives were:

- Capacity building
- To Set up the GIS Portal Toolkit on a Server data and Webserver

The outcomes from this SDI-Training are:

- A National Portal under construction is available on the data server at RITA (Rwanda Information Technology Authority) (see figure 3.3)

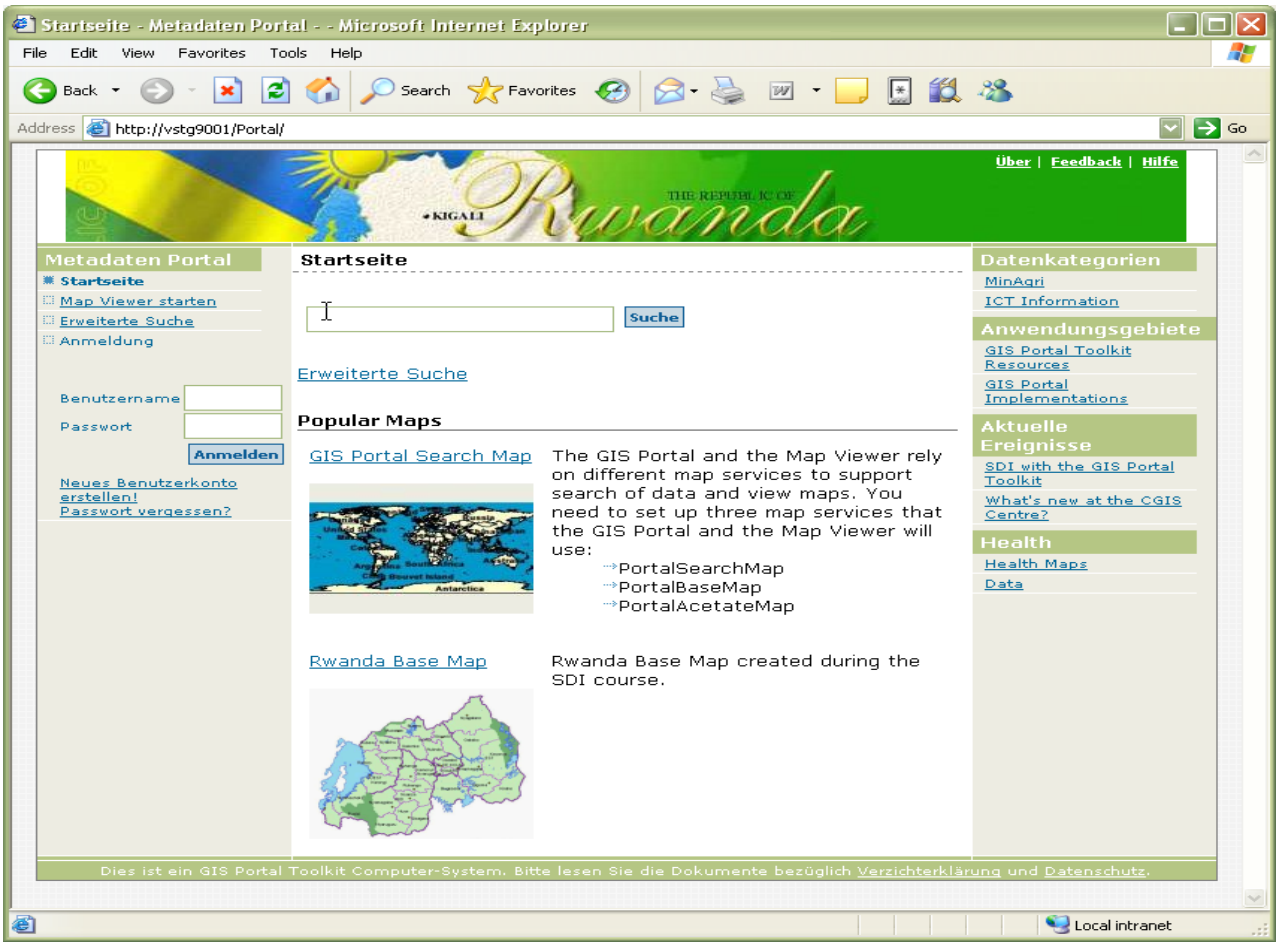

Figure 3.3: A National Portal under construction in Rwanda

- A Portal for CGIS at CGIS&RS-NUR on the Webserver meaning that this portal is available on internet (visit this URL: http://www.cgis.nur.ac.rw/Portal/).

Figure 3.4: A Portal for CGIS at CGIS&RS-NUR

- In 2007 RITA initiated the metadata collection from different Ministries. The purpose of this action was to show what it is available on the Portal and its functionality to a bigger audience.

IV. CONCLUSTION AND RECOMMENDATIONS

This study will contribute a lot in terms of knowing the followings:

☞ What data are available?

The table 3.1 of framework data sets in this study shows spatial data and their Custodians in Rwanda. This table gives a list of data for instance data about Administrative Boundary, Transportation, Hydrology, Elevation, Cadastral etc…

☞ Where to find the data?

The same table (Table 3.1) shows which department is responsible of what data set in Rwanda. Knowing where to find data this will help to save time and much money spend look for data for users of spatial data and researchers.

☞ How to access the data?

The design of a proposed workflow of data sharing for Rwanda (see figure 3.2) shows where inputs are initiated, the location of decision points and the alternatives in output paths. This design will contribute a lot in the development of the policy of data distribution and sharing in Rwanda from local to national level.

The author collected data during fieldwork in Rwanda at different institutions in private and government using questionnaire and other instruments such as desk studies, literature review, internet and observation have been used in this study.

The table 3.1 gives available framework datasets and this shows that the objective which consists of determining which framework data sets are in existence in Rwanda and their Custodians has been achieved.

The author recommends further study in creation of a committee, the NGDC (National Geographic data committee which can co-ordinate the development of infrastructure needed to support the utilization of the activities related to a National Spatial Data infrastructure (NSDI) in decision making. This committee could have also oversees and coordinates. This committee should also define the policies, legal procedures and standards to collect metadata, publish and share spatial data.

The author encourages partnerships organizations and to get the permission to upload some datasets and to make it accessible through the Portal on internet.

Partnerships are the glue all the components of the NSDI (i. e. clearinghouse, metadata, framework data, geo-data). Partnerships between different institutions extend local capabilities into technology, skills, logistics, and data. Partnerships minimize costs and save time. In practice, partnerships can reduce the long-term cost of NSDI in three major ways:

- First, partnerships are an effective way of achieving consensus. Instead of each agency acting independently, partnerships create a sense of shared responsibility for the product and its use.
- Second, partnerships can encourage a clear division of responsibilities even when the data needs are shared.
- Third, division of responsibilities within partnerships can promote investment so that new ways of reducing costs can be developed entirely. Salaries account for by far the largest share of the costs of spatial data, whether they are paid to digitizer operators, programmer analysts,

or field workers. The most effective ways of reducing those costs lie in better technology and better training.

The author recommends the implementation of data sharing policy, the use of a common standards and institutional aspects like legal framework (i.e.: Copy right, privacy/confidentiality, and security), and financial aspect of accessing data or pricing policy.

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References

Journals

FAO and SKE Inc. (2001). The concept of "core" or framework data. USA. Food and Agriculture Organization of the United Nations

The office of the president (2003). Spatial Data Infrastructure Act, 2003.Vol. 464. Cape Town. Government Gazette: No. 54.

Ottichilo, Wilber K. (2006). Kenya national Spatial Data Infrastructure policy formulation process initiative. Nairobi. SDI-Africa Newsletter, Vol. 5, No. 2

Hans Dufourmont, Alessandro Annoni and Hugo De (2004) INSPIRE - work programme Preparatory Phase 2005 - 2006 .ESTAT-JRC-ENV

Published Papers

Chiwozva, Gerald (2006): The Role of Standards in Spatial Data Infrastructures - The Zimbabwe Case. Harare. Standards Association of Zimbabwe

Loenen, Bastiaan van (2003): The Impact of Access Policies on the Development of a National GDI. Nederlands. Department of Geodetic Engineering, Delft University of Technology

Nebert, Douglas (2004) National Spatial Data Infrastructure: Concepts and Components. USA. Federal Geographic Data Committee Secretariat

Lieberman, Joshua (2007). OpenSDI: Use Cases and Information Models for a People. Spatial Data Infrastructure. USA. Traverse Technologies, Inc.

Masser. Ian (2002) Report On A comparative analysis of NSDI's In Australia, Canada and the United States. USA. University of Sheffield – USFD. Open GIS Consortium (Europe)-OGCE

Warnock, Archibald (2007). National Geospatial Data Clearinghouse. USA. Federal Geographic Data Committee and A/WWW Enterprises

Karatunga Ali Mohammed. (2002) The Uganda Spatial Data Infrastructure framework. Addis Ababa, Ethiopia; Kampala, Uganda. Karamoja Data Centre

Groupwork . (2005) Proceedings Kenya National Spatial Data Infrastructure. Kenya. Kenya Institute of Surveying and Mapping Survey of Kenya.

Cesare Mbaria (2005) Experience towards establishment of national of a National Spatial Data Infrastructure (NSDI) in Kenya. Narobie, Kenya. Survey of Kenya Field Headquarters.Geodetic and Computer Services Division/NSDI Secretariat.

Richard Kasuga. (2005) Towards SDI Decision Support for Agricultural Planning in Tanzania. Workshop in Cairo, Egypt.

Groupwork (Deo Rutamu Dr. Michele and E. Muyombano). (2006) Geo- ICT for Development in post-conflict areas Toward a National Spatial Data Infrastructure for Rwanda. Butare, Rwanda. CGIS-NUR.

Deo Rutamu (2006) Workshop: Toward a Spatial Data Infrastructure in Rwanda. Kigali, Rwanda. CGIS-NUR. (http://www.cgisnur.org/IMG/pdf/Agenda_SDI_Conf.pdf)

Ferdie Danzfuss and Judith Bishop (2005) Lessons learned from building a web-based spatial data discovery facility. Pretoria, South Africa. Computer Science Department, University of Pretoria

Environmental Information Systems (EIS) Unit. (2003) Namibia's Spatial Data Infrastructure draft Spatial Data Infrastructure Policy. Namibia. MET.

Alan R. Steven (2004).The US National Spatial Data Infrastructure. Virginia, USA. Federal Geographic Data Committee (FGDC).

Conference Papers

Alan R. Steven, Harlan J. ONSRUD and Mukund RAO (2004) Global Spatial Data Infrastructure (GSDI): Encouraging SDI development initiative. China

Ian Masser, Wilson Robby and John McLaughlin (2005) Workshop: Service and Application of Spatial Data Infrastructure .The future of Spatial Data Infrastructures. London. Centre for Advanced Spatial Analysis, University College London

Workgroup. (2001) Recommendation from the Nairobi conference
Spatial information for sustainable development. Nairobie, Kenya

Kalande W. and Ondulo J. D. Kenya (2006) Workshop: Geoinformation Policy in East Africa (Kenya, Tanzania and Uganda). Munich, Germany

Ali Mansouriana, Abbas Rajabifardb and Mohammad Javad Valadan Zoeja (2005) Workshop: Service and Application of Spatial Data Infrastructure SDI conceptual modeling for disaster management -SDI components. Tehran, Iran. Faculty of Geodesy & Geomatics

Internet or Websites sources

GeoConnections (2006)
www.geoconnections.org/publications/Technical_Manual/html_e/cgdiindex.html
http://www.geoconnections.org/publications/Technical_Manual/html_e/s1_ch1.html#1.3
Access date: 2/11/2006

U.S. Federal Geographic Data Committee (US. FGDC)
http://www.fgdc.gov
GSDI Secretariat: http://www.gsdi.org
Access date: 04/11/2006

SDI Evolution in the US: Solid Technology, Policy Changes, Hard
www.fgdc.gov/library/presentations/presentations/sdi-evolution-0904
Access date: 29/10/2006

National Spatial Information Framework
http://www.nsif.org.za/
Access date: April 20, 2007

The ANSI/NISO Z39.50 Protocol: Information Retrieval in the Information Infrastructure
http://www.cni.org/pub/NISO/docs/Z39.50-brochure/50.brochure.part01.html
http://www.cni.org/pub/NISO/docs/Z39.50-brochure/
Access date: 22/12/2006

Building a database-driven Web site! SitePoint.com
http://dev.mysql.com/tech-resources/articles/ddws/2.html
Access date April 15, 2007

Promoting the National Spatial Data Infrastructure Through Partnerships
http://newtown.nap.edu/html/partnership/index.html
Access date: November 05, 2006

CGIAR-CSI (2004), functions of Clearinghouse
http://csi.cgiar.org/metadata/Metadata_Why.asp#Definition%20of%20Metadata
http://csi.cgiar.org/metadata/Metadata_Why.asp
Access date: December 25, 2006

ISO/TC 211 Geographic information/Geomatics
http://www.isotc211.org/
Access date: February 12, 2007

World Wide Web Consortium
http://www.w3.org/Consortium/
Access date: February 20, 2007

What is a Clearinghouse?
http://www.mediascape.ac.nz/content/about_us/clearinghouse
Access date: February 18, 2007

The responsibilities of RITA
http://www.rita.gov.rw/about.htm
Access date: May 20, 2007

The responsibilities of RDG
http://www.rwandagateway.org/article.php3?id_article=55
Access date: April 12, 2007

Initial objectives of CGIS
http://www.cgisnur.org/article.php3?id_article=35
Access date: April 15, 2007

Definition of Web server
http://www.elms.edu/departments/library/AcademicReferenceResources/GlossaryLibTerms.htm
Access date: May 23, 2007

Definition of a Custodian
http://www.michigan.gov/cybersecurity/0,1607,7-217-34415---,00.html
Access date: May 28, 2007

ITC (2007)
http://www.itc.nl/sdidm07
Access date: September 16, 2007

GSDI (2006)
http://www.gsdi.org/SDIA/docs2006/jul06links/nat_sdi_uganda.html

Access date: September 16, 2007

Published books

Zhong-Ren Peng and Ming- Hsiang Tsou (2003). Internet GIS .Distributed Geographic Information .Services for the Internet and Wireless: New Jersey (USA): Hoboken

Douglas D. Nebert, (2004) Developing Spatial Data Infrastructures: The SDI Cookbook. Australia: Steve Blake; Germany: Frank Lochter; USA: Allan Doyle

Paul A. Longley, Micheal F.GoodChild, David J. Maguire and David W. Rhind (1999) Geographical Information System. Second Edition. Volume 2. USA. John Wiley and Sons, Inc

CEAD_LIM, University of Kwa-Zulu Natal (Year 2006)

Data Sharing, the Geospatial Data Infrastructure (GDI) and Metadata (2006)

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