Nationwide Geographic Information System- A Cost Effective and Efficient Approach to Meet the Challenge of Sustainable Development in Bangladesh

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ABSTRACT

A sustainable development program can not be pursued without performing detailed analyses on environmental issues, natural resources and infrastructure conditions. For such analyses, accurate information and appropriate technology need to be available. More than 80% of the information required for this purpose is spatial in nature, i.e. the information needs to be referenced by locations. Over the last few years, geospatial technology has advanced extensively in spatial data collection and analytical capabilities. With Geographic Information System (GIS), environmental scientists can synthesize and analyze data, develop predictive models and integrate their findings into a decision support system for faster and better solutions. However, implementation of GIS is expensive, particularly the data acquisition component. To cope with this large initial cost, several countries are taking an approach to develop nationwide or statewide GIS framework, which allows multiple users to share the benefits of GIS and thereby share the cost. Cost-sharing of GIS implementation is the only solution for a country like Bangladesh, which needs GIS for environmental and economic analyses but has financial limitations. Multiple users can share the system for multiple projects, only if GIS data and technology meet their requirements and standards. National level policies are required to make a nationwide GIS framework functionally efficient and cost effective by ensuring data quality and standardization, and avoiding duplication of data acquisition. From environmental and sustainable development prospective for Bangladesh, making the most efficient decisions is critical. A nationwide GIS framework can support such a decision making process by providing accurate data and analytical capabilities.

INTRODUCTION

Information regarding "what" and "where" is essentials for effective decision making process. Geographic Information System (GIS) enables the use of such information to make quick decisions (efficient) and correct decisions (effective). GIS is an information system designed to capture, manage, manipulate, analyze and display spatially referenced data for solving complex planning and management problems. With the capability of analyzing data that has location (spatial data) and description (attribute data), GIS has been proven effective for economic development, improving stewardship of natural resources and protecting the environment (Lang, 1998; Freeman, et al., 1998 and ERIN, 1997). Because of long-term cost effectiveness and efficiency in decision making process, GIS has been increasingly implemented all over the world, both in developing and in developed countries (Masser, 1998a; Masser 1998b; Masser 1998c; NGDF, 1998; NAPA, 1998; Hobman, 1997 and Standley, 1997).

There are five components of GIS: data, hardware, software, people and methods. The initial costs of these components are high. Particularly, data generation, which constitutes 60% to 80% of the total cost, is a major financial constraint to GIS implementation. But if these data, generated by one agency are shared by others, cost-sharing can make the data acquisition cost-effective. However, to make the data useful for multiple agencies, a common data standard needs to be adopted. In addition to data, the common standards for other components of GIS (hardware, software, people and methods) will make GIS acceptable and useful to all potential users. To deal with the initial cost and to improve the efficiency of GIS, several countries including the United States, have adopted an approach to develop nationwide or statewide GIS framework (TGIC, 1999; AGIC 1993; FGDC, 1995; MSGIC, 1993 and 1996; NSGIC, 1998; NGDF, 1998; and ANZLIC, 1997). Bangladesh needs such capability, probably more than any other country to cope with its tremendous population pressure on limited natural resources. This immense task requires planning and implementation of a sustainable development program that guides the environmental restoration and prevention of further pollution. A nationwide spatial information system will enhance the coordination among government agencies, international funding agencies, NGOs and private sectors, and will help to achieve common national interests for Bangladesh. The nationwide GIS framework for Bangladesh, governed by appropriate policies and well-defined standards may be called "Nationwide Geographic Information System" or NWGIS per se. The key aspects of NWGIS framework will include issues related to a) common data layers required for Bangladesh, b) procedures, technology and guidelines for integration, sharing, and use of these data, and c) organizational structure, institutional relationships, and business practices for maintaining and using GIS.

Environmental analysis requires multidisciplinary data. A vast majority of these data are spatial in nature, and falls under the domain of GIS. This paper discusses the steps involved in developing a framework of GIS which ensures 1) data quality that can be trusted, 2) a technology that works, and 3) a decision making process that can be efficient and effective.

This paper outlines a nationwide GIS initiative for Bangladesh without giving details of implementation technicalities and design specification.

STEPS TOWARDS NWGIS

A good number of countries have implemented or in the process of implementing statewide, nationwide and even multi-national GIS framework. With few exceptions, most GIS frameworks involve very similar steps. Brief descriptions of the basic steps for NWGIS are described below from the context of Bangladesh:

1. Formation of Coordinating Council
2. Strategic Plan
3. User Needs Study
4. Determination of Policy Issues
5. Implementation Plan
6. Data Generation
7. Implementation

Coordinating Council

For the success of a nationwide GIS, strong inter-agency coordination is critical. A national body composed of stakeholders of such a project may be called the NWGIS Coordinating Council, per se. Usually, a legislative act mandates such a council with general guidelines and overview of the formation of the council and its role (State of Mississippi, 1999 and State of Louisiana, 1995). The council plays a pivotal role in developing guidelines for a nationwide GIS by initiating the process, organizing the stakeholders, conducting research, and most importantly, establishing the policies. The council also plays a role in budget appropriation and implementation of the project. It establishes a platform where the multi-disciplinary agencies can express their needs and concerns, which gradually shapes the NWGIS framework. The council establishes a mechanism for coordinated GIS to 1) address spatial data standards, data sharing, documentation, maintenance, compatibility and transferability, 2) integrate disparate data sets in order to avoid duplication of effort, 3) design partnerships for the coordinated development of data collection programs, and 4) establish a GIS clearinghouse.

Any organization that generates spatial data or uses such data needs to be able to contribute to this effort. Hundreds of organizations including governmental, non-governmental, private, and voluntary organizations in Bangladesh are engaged in spatial data use and/or generation. However, it is not often easy to achieve consensus with large group within a reasonable amount of time. To solve this problem, two approaches may be taken. Voting authority can be restricted to a specific number of members who have policy decision jurisdiction. To ensure a wider base of participation, subcommittees can be formed with a mixture of voting and non-

voting members who will take responsibility for certain tasks and present that to the full committee. In this manner, a larger number of organizations will be able to participate but formal decision making will not be affected by chaos and delay. The other approach may be to restrict the membership only within certain type of agencies, such as government agencies. However, the latter approach has the drawback of missing the big picture due to limited participation.

The responsibilities of the council include but are not be limited to: 1) defining the vision, mission, goals and objectives of NWGIS, 2) identifying and analyzing current conditions of spatial data capture, use and transfer within the country, 3) conducting research on similar programs undertaken by other countries with similar objectives, 4) defining characteristic components of NWGIS, which includes data, technology and procedure, 5) establishing policies regarding data standard and format, data accuracy and scale, data distribution, data security, data updating responsibility and inter-agency coordination, 6) developing a phase-wise implementation plan with cost and timeline, 7) defining training and technical support program. The first product developed by the committee will be a detailed report regarding the strategic plan of developing the NWGIS for Bangladesh, which will guide the implementation of the NWGIS initiatives. An executive summary report also needs to be prepared from the detailed strategic plan and presented to the legislative body of the country. The committee should be vested with enough authority and flexibility so that the ongoing and future nationwide activities can be incorporated into the strategic plan as it evolves. It is critical that NWGIS concurs with other national projects and coordinates with international organizations, government agencies, NGOs and private sectors.

Strategic Plan

As mentioned in the earlier section, a strategic plan will be the first product developed by the NWGIS Coordinating Council. The strategic plan will guide the required studies, policies, implementation plan, GIS data generation and actual implementation. Issues related to budget and required resources are also addressed at this stage of the initiative.

User Needs Study

GIS needs vary depending on the user community. A detailed needs assessment is a prerequisite of the implementation plan. Interviewing respective agencies, visiting their facilities and studying their current, planned and historical trend of spatial data use are the primary methods of data collection for this phase. This study should be incorporated with national goals of short- and long-term plans. The needs assessment report will aid the coordinating council committee in defining the characteristics of NWGIS in the areas of data, procedure, and technology.

Policy Issues

Without having a national policy that ensures the collection of quality data that is useful and available to the users, NWGIS will not serve its purpose. Establishing the policies will be substantially guided by the Needs Assessment report. Aspects that need to be covered by policies are: a) data, b) procedures, technology and guidelines for integration, sharing, and use of these data, and c) organizational structure, institutional relationships, and business practices for maintaining and using GIS . Issues that must be included in the policy deliberations are: 1) Data Standard and Format, 2) Accuracy, Resolution and Scale, 3) Distribution and Access, 4) Security, and 5) Updating.

Data Standard and Format

Information contained in database fields needs to be useful, meaningful and analyzable by potential users. Conventionally (paper or hard copy) collected and stored spatial data and their descriptions require proper conversion into digital format to be used in GIS. With current technologies, such as GPS and a variety of remote sensing technologies, data can be directly collected in digital formats as well. Whether through direct collection or conversion, GIS data must be standardized, so that one data set can be readily integrated into another data set, irrespective of the collecting agency and the location they were collected from. Standardization of the field (item) definition and number of fields in a data layer (theme) is the basic step to ensure integration among multiple databases of the same theme. The other aspect of standardization of spatial data refers to projections, datums and units. The user community has to agree on these standards and the Coordinating Council has to mandate the standards to avoid future confusions.

Digital GIS data formats are designed by a variety of software vendors in raster format, such as E00, .DXF, .DGN or in vector format, such as TIF, .GIF, .SID. Different agency-developed data formats are also available such as, TIGER, DLG, and DEM, which can be imported and used by most common software. In recent years, a concept of universal data format that can be readily used by different software is becoming popular. Integration and use of different data sets will depend on data format and that has to be selected before implementing the data collection phase.

Accuracy, Resolution and Scale

Accuracy refers to the correctness of data, for spatial (horizontal and vertical) and descriptive data. Data accuracy is directly related to the collection effort, system, and original source (if converted). Accuracy must be defined at the initial stage of planning.

The term resolution (spatial resolution) usually applies to images-- satellite images and orthophotos. Images are represented by 2-dimensional array of cells or picture elements known as pixels. Size of pixel defines the resolution of an image. The smaller the pixel size, the better the resolution. How small an object can be detected on an image is defined by the pixel size and hence by the resolution or quality of the image.

Scale represents the dimension of features as displayed on a map (paper, monitor, etc.) relative to its real dimension on the surface of the earth. Publishing a map with better (larger) scale requires better accuracy of the data. Standards for map scale and accuracy have been established by several organizations, among them the US National Map Accuracy Standard (NMAS) is common.

Background information of collected data which is known as "Metadata", must be available to the users. Metadata are "data about data", which help the users to learn about the content, quality, condition, usefulness, and other condition of data (FGDC, 1998). The adopted standard, format and metadata structure need to be mandated through proper governmental procedure. Spatial data quality is related to accuracy, resolution and scale. For a nationwide system, the data quality needs to be controlled and consistent, and the information needs to be maintained and made available to the users, including metadata.

Distribution and Access

How the data will be distributed to and accessed by the users, needs to be formulated by the Coordinating Council and supported by national administrative policies. The basic concerns are to decide 1) who will be responsible for distribution, 2) who will have access rights, 3) what will be the technology, and 4) how will the cost (maintenance, reproduction or production cost) be recovered.

GIS is a computer based information system. Internet, which serves as the "information super-highway", plays an important role in dissemination of GIS data. Most countries that have started to use GIS have a solid infrastructure for Internet access. Depending on the current condition of Internet and future plans in Bangladesh, the role of Internet for GIS data distribution and access needs to be determined. Without having Internet access, data can be made available on CD or on similar media.

Updating

Some of the GIS data need to be updated over time as the location of the features or their attributes change over time. Usually, the agency that has originally collected the data, will be the most suitable to have the updating responsibility. However, if updating is not of direct interest to

that agency, costs involved in updating may be an issue. Budget appropriation needs to be assured by policy makers in such cases.

Security

The least obvious but most critical aspect is the issue of security. Lack of security can not only jeopardize the investment of NWGIS but can cause further disaster if corrupted data is used for any project. It must be ensured that data can not be modified by anyone other than the authorized agency and designated personnel. Authorization and prohibition must be mandated by strong and clear administrative policy.

Funding

It is not the adequate funding, but an effective funding policy, which can make the NWGIS cost effective and operational. Currently, several mega-projects are planned or being implemented in Bangladesh. Some of these projects require the same spatial data layers. For example, digital orthophotographs can be used both for nationwide property map creation as well as for projects related to flood action plans. Similarly, once the topographic data is collected with proper accuracy and format, the data can be used for multiple projects, such as flood action plans, regional irrigation projects and even for construction projects. The key to support GIS data acquisition is through proper allocation of funding which is already available or under consideration for a project that requires spatial data. Other than data generation, stable funding is required for operational costs. Maintenance of hardware, software, physical facilities and training are main components that will require dedicated funding. One more important issue is to have a phase-wise option, so that in case of limited funding, specific phases get completed and the country starts to accrue the benefits.

Implementation Plan

The Implementation Plan follows the Strategic Plan developed by the Coordinating Council. The Implementation Plan is more detailed and less flexible than the Strategic Plan. It includes the design phase of the project. Usually a pilot study is an element of the Implementation Plan.

Data Generation

As mentioned earlier, data is the most expensive component of GIS, which is about 60% to 80% of the total cost. The cost can be reduced significantly by avoiding duplication in data acquisition efforts and assuring data sharing among different organizations

Framework Data

It is critical to determine what types of data are most commonly used by maximum number of users. In the United States, studies have been done to determine the most common data used by most organization. In a recent study in the United States seven different data layers have been identified and referred to as "Framework data" which are: geodetic control, orthoimagery, elevation, transportation, hydrography, governmental units, and cadastral information (FGDC, 1999). Other countries who have taken a nationwide GIS approach have recommended similar data layers with a few additional or less layers. If Bangladesh moves forward to pursue for NWGIS, the following brief description of the most widely used data might be useful for the initiative.

Geodetic Control

Geodetic control features are used for tying all geographic features to a common, nationally used horizontal and vertical coordinate system by providing a common reference system for establishing the coordinate positions. Geodetic control is the core of controlling the positional accuracy of spatial data. In the framework environment, the geodetic control layer includes monuments that are very precisely measured horizontal and vertical locations and include detailed information about the control features. In addition to the existing geodetic monuments, new control stations, established by Global Positioning System (GPS) are required to accommodate an adequate referencing system for Bangladesh.

Orthoimagery

Digital images of the earth, which are georeferenced and rectified for relief and sensor-related displacements are called orthoimages. In other words, these images can be displayed with proper location while overlaid with other geographic data of the same area. Orthoimages can be prepared from aerial photographs (orthophotos), from satellite images, or from other remote sensing platforms. Images are composed of picture elements (pixels) which represent the ground reflectance values and are arranged in a discrete but uniform fashion.

A majority of the framework data features can be identified on the orthoimages and can be derived from those images. Orthoimages can also be used to generate project specific derivative/interpretative maps. They can be used for design and construction purposes if the resolution of the image is high enough. For urban area, low-altitude high-resolution orthophotographs are required. For example, for a statewide GIS program for the State of Tennessee, USA, orthophotographs are required to be at 1:30,000 scale for rural area and 1:7,500 scale for urban areas (State of Tennessee, 1999). The Tax Commission of the State Mississippi, USA, recommends orthophotos at 1:24,000 scale for rural area and 1:6,000 scale for urban area. Considering the population density and cost of lands in Bangladesh, orthophotos for urban areas should be at least 1:7,600 scale or better. Aerial photo scale depends on the three interrelated factors: camera focal length, altitude and negative scale. Negative scale = Altitude / Focal length. Quality of aerial photographs depends on several

factors, such as flying condition, camera resolution, sun angle, film type, terrain condition, GPS navigation and so on. Inertial Measurement Unit (IMU) technology assures better positional accuracy over traditional Aerotriangulation procedure. Flight planning and layout with appropriate overlapping (a minimum of 60% forward overlap and 30% side overlap is common) and tiling system should be performed and need to be approved before data capture.

The procedure of making digital orthophotos involves scanning the original negatives of aerial photographs with proper specification, georeferencing the scanned images with reference to GPS/IMU data, and rectifying the relief effect using DTM data. Pixel size for 1:30,000 or 1:24,000 scale orthophotos should be 2ft x 2ft and for 1:7,500 or 1:6,000 scale should be 0.5ft x 0.5ft to maintain the proper resolution. At the end of year 2000, the technology of directly collecting digital orthophotograph may be commercially available which will substantially reduce the time and cost of orthophoto production.

In addition to photographs, orthoimages can be non-photographic airborne images or satellite images. Satellite images with low spectral resolution but wide coverage, temporal data availability and reasonable cost are excellent sources for regional studies. Recent developments in achieving higher resolution in image quality, satellite images have begun to compete with orthophotos. The new remote sensing satellite, Ikonos is now providing 1m resolution Panchromatic (black and white) and 3m resolution multi-spectral images. In the year 2000, there will be several high-resolution satellite images available. In the absence of digital orthophotos, these satellite images can be good sources to generate derivative/interpretative maps and also to verify locations of features on the earth that are collected by other methods, such as RADAR (Radio Detection and Ranging) or LIDAR (Light Detection and Ranging).

Elevation

Elevation data refers to a spatially referenced vertical position that provides information about terrain. Digital elevation data can be represented: 1) in a raster model by grids with certain cell sizes (resolution), commonly known as Digital Elevation Model (DEM), 2) in a vector model, represented by contours or points with x, y and z values, or 3) in a Triangular Integrated Network (TIN) model. Irrespective of data models, all types of computerized elevation data are commonly known by a generic term, the Digital Terrain Model (DTM). DTM data is one of the most important data layers in a GIS, which forms the topographic base map for GIS modeling. It is the foundation for hydrologic modeling, determining site suitability, engineering planning and design, slope stability and so on. Particularly, for flood control related projects, accurate and updated DTM is critical. Determining water flow direction, delineating watersheds, calculating the volume of water in a basin, simulating flood in a given condition are examples of use of elevation data in flood control projects using GIS. Because of very gentle slope for most parts of the country, elevation data should be collected at the highest level of accuracy within reasonable cost. The accuracy should be at least 15 cm or even 10 cm for the

deltaic floodplain areas. It is better to store the elevation data as point features with x, y, and z values, that can be easily groundtruthed and converted to grid, TIN or 3D models.

Transportation

The major features of transportation data include: 1) Roads, 2) Railroads, 3) Waterways, 4) Airports and other ports, 5) Bus terminals, 6) Bridges, and 7) Power line and pipeline corridors. All features should be captured with proper attributes and spatial accuracy. Depending on national needs, roads and railroads can be represented by centerlines, edges, or rights-of-way.

Transportation data can be captured manually using GPS or derived from remotely sensed data. For nationwide data compatibility, a common standard for accuracy and database must be maintained. Data that have been already collected through several different programs need to be accumulated, standardized and prepared for nationwide database. The transportation database can be used not only for planning and development purposes but also to develop an inventory with names of government individuals and contractors responsible for maintaining/constructing the features, technology/methodology applied, and other relevant information to evaluate the performance.

Hydrography

Hydrography data should include all surface water features such as rivers, streams, canals, lakes (including beels haors, etc.), bays, oceans, and shorelines. All features should be coded with unique identification numbers and attributed with pertinent information. Water level variation should be recorded with associated temporal data. Waterways need to be mapped with depth of water as attributes. Waterways can be incorporated to transportation theme with required attributes. Quality hydrography data is extremely important for Bangladesh to address environmentally oriented problems, such as flood, pollution, land suitability, aquatic habitat and so on.

Governmental Units

Governmental units include boundaries for the country, administrative boundaries for divisions, districts, upazillas/thanas, towns/cities, voting precincts, and other political boundaries. These features need to be mapped by closed polygons and attributed with classification codes, names and with census data where possible.

Cadastral

Cadastral refers to information pertaining to real property. By definition, cadastral data represent the past, current and future rights and interests in real property. Cadastral mapping

requires information from survey, legal description, reference systems, and parcel-by-parcel surveys and their descriptions. For rural area the mapping scale can be relatively large, such as 1:48,000. On the contrary, in urban areas it has to be smaller, such as 1:1,200 or even smaller depending on the property values and sizes of parcels. Because of the scarcity of land in Bangladesh, GIS mapping of cadastral data will probably be the most sensitive issue among people. There are several ways to accomplish cadastral mapping with varying accuracy and costs. The best method for Bangladesh will require further research regarding cost effectiveness and accuracy applicable for the country.

Cadastral data include the smallest unit among all other framework data category and provide an excellent opportunity for high precision data attribution. The fundamental attributes include property identification number (PIN), owner's description and property tax related data. Other data that are linked with the cadastral database include description of occupancy, current and past land use, zoning, and structure on the property. Property maps are enhanced by texts which commonly include PIN, area, boundary dimension, road/street names and dimensions, and block, sector, etc. where applicable.

In the long run, cadastral GIS will support the resolution of problems, lawsuits and conflicts of land property issues. The cadastral data layer is also instrumental for many analyses, decision making and operational applications, such as for land use administration, site selection, transportation planning, water distribution planning, waste water management planning, waste disposal planning and so on.

In addition to the above mentioned framework data, several other countries who are implementing or planning to implement a nationwide GIS, have included few other layers which are not included in US Framework data, such as geology and soil.

Because of the extreme pressure on natural resources in Bangladesh, additional framework data, such as geology and groundwater may be required.

Geology

Surface geologic mapping at 1:24,000 scale for the whole nation will be a useful guide for land use planning and even for construction design in certain areas where geologic problems are unique. The geologic database should include unit name, age, major and minor properties, major and minor mineral constituents, notable geologic features, resource potentials, and hazard potentials of the geologic unit. Over the years, with the availability of detail subsurface geologic investigation, a subsurface geologic database can be evolved. A nationwide GIS inventory of water wells, hydrocarbon wells, engineering bore holes along with geophysical findings needs to

be developed. The success of such an inventory will require a strong national policy to mandate all public, private, NGOs and international agencies to provide such information to the data collecting body (to be determined by NWGIS). Coordination between geologists and GIS specialists will be required to successfully interpret these data and integrate them into GIS.

Groundwater

The unique situation of groundwater quality and quantity issues in Bangladesh will require the development of a groundwater GIS database. A foundation of such a database should be established while developing the geologic database. Specific groundwater related historical data and further investigation generated data need to be incorporated into the subsurface geologic database. The database should be designed and developed in a way so that it will answer groundwater development related questions and aid in decision making process for sustainable groundwater resources.

In addition to the above data, GIS databases with themes for soil, wetland, flood control/regulating structures, forest, ecology, mineral resources, land-use, environmentally sensitive areas, and waste disposal sites are essentials for resource management, economic growth and environmental management. Any additional framework data requirements should be determined by the NWGIS based on the study of needs assessment, current status and future plan.

Implementation

As other aspects of NWGIS, implementation issues need to be guided by policies adopted by the Coordinating Council. Major issues in implementation include: a) Storage and Distribution, b) Analysis, c) Update, and d) Training and Support.

Storage and Distribution

Storage issues include the media and technology to be used for data storage, the physical infrastructure, and responsible authority. Similar to storage, distribution issues also include the media and technology to be used for data distribution, the physical infrastructure, and responsible authority. Because of the rapid advancement in technology in the areas of digital data storage and distribution, up to date research needs to be performed for selecting the appropriate technology.

Analysis

Analysis capability is a function of data structure, software, method and expertise of the analysts. These issues need to be guided mostly by the coordinating council's decision based

on the vision, users needs assessment, current status and future plan. The general criterion is the compatibility of these issues with each other. Data must be compatible with the software, methodology should be available to achieve the answer and personnel should have the expertise to perform the analysis.

Update

Usefulness of data depends on timely update. While the majority of the framework data will not require frequent updating, some themes or parts of themes will require more frequent updating. For example, when river courses and shorelines change or when new roads are constructed, changes are to be incorporated into the appropriate data layer. The most dynamic data layer is the cadastral, as the ownership, property dimensions and land properties are constantly changing. For certain data layers, such as cadastral, updating authority should be strictly restricted to the agency who generates and maintains the respective data.

Training and Support

Without a proper training and support program for NWGIS, the initiative can never be successful. Two types of expertise and skills will be required. A small number of experts with thorough understanding of geospatial technology, its evolving nature and special needs for Bangladesh will be required. This group will work closely with the policy makers. Another group of skilled professionals needs to be created through training and support program that will be engaged in the production process. This large number of skilled people will not only develop the NWGIS but also will impact the techno-economic future of Bangladesh. The young generation with their usual Bangladeshi talents is eager to learn new technology. Very few of them actually get the opportunity to learn and even fewer get the opportunity to implement. During the data generation phase, the NWGIS will create a good number of skilled professionals who will be able to use their computer and information based skills in other areas after the project is completed. While the cost of training and support is insignificant relative to the total cost, continuous funding and well-defined policy for training and support play a significant role in the success of such a project.

CONCLUSIONS

It is a challenge for Bangladesh with its immense population pressure and limited natural resources to achieve economic growth while protecting the environment. The country needs to get prepared to face this challenge with the most suitable technologies and strong policies. Information is power. GIS is effective and efficient in understanding and managing the environment because of its ability to use spatial information. Improved decision making can come through the proper use of combining data sets to reveal a more accurate picture. To cope with the high costs of GIS, a coordinated GIS approach, known as GIS framework, is becoming popular all over the world. Implementation of GIS framework with well-defined

policies will prepare Bangladesh to face the challenges of sustainable development for the twenty-first century.

REFERENCES

ANZLIC, 1997, STRATEGIC PLAN 1997-2000, http://www.anzlic.org.au/stratplan.htm

AGIC, 1993. Arizona Geographic Information Council (AGIC) Strategic Plan 1993, http://www.land.state.az.us/agic/web_n/web/pubs2.htm

ERIN, 1997. Environmental Resources Information Network Strategic Plan 1997-2000, http://www.environemnt,gov.au/psg/erin/strat_plan/

FGDC, 1995. Development of a National Digital Framework, Federal Geographic Data Committee, April 1995, http://fgdc.er.usgs.gov/framework/framdev.html

FGDC, 1998. Content Standard for Digital Geospatial Metadata, Metadata Ad Hoc Working Group, Federal Geographic Data Committee, Reston, Virginia 20192, USA

FGDC, 1999. Overview: What the framework approach involves, Federal Geographic Data Committee, 1999, http://fgdc.er.usgs.gov/framework/framework.html

Freeman, N., Boston, T. and A. Chapman, 1998. Integrated Internal, Internet and Internet Access to Spatial Datasets via ERIN's Environmental Data Directory, http://www.environemnt,gov.au/database/AURISA-98/freeman.htm

Hobman, L., 1997. The National Geospatial Data Framework: From Concept to Reality, AGI, GIS'97, http://www.ngdf.org.uk/Pubdocs/Pubpapers/lhagi97.htm

Lang, L., 1998. Managing Natural Resources with GIS, ESRI Press, 1998, 144 pp

Masser, I. 1998a. The first generation of national geographic information strategies, paper presented at SDI'98, Ottawa, June 9- 11 1998

Masser, I. 1998b. *Governments and geographic information*, London: Taylor and Francis

Masser, I. 1998c. An International Overview of Geospatial Information Infrastructures: Lessons to be Learnt for the NGDF, National Geospatial Data Framework, UK

MSGIC 1993. 1993 MSGIC Strategic Plan, Maryland State Government Geographic Information Coordinating Committee (MSGIC), http://www.msgic.state.md.us/publicat/stratpln/index.htm

MSGIC 1996. Addendum to MSGIC's Strategic Plan, Maryland State Government Geographic Information Coordinating Committee (MSGIC), http://www.msgic.state.md.us/publicat/stratpln/96adend.htm

NAPA, 1998. *Geographic information in the 21st century: building a strategy for the nation*, Washington: National Academy of Public Administration

NGDF, 1998. Establishing the UK National Geospatial Data Framework Strategic Plan – 1998, http://www.ngdf.org.uk/Pubdocs/Pubpapers/strat99.htm

NSGIC, 1998. National States Geographic Information Council (NSGIC) Strategic Plan, Draft Approved by the Council, September 16, 1998

Standley, T., 1997. GIS Implementation in Developing Countries- A United Nations Perspective, GIS Qatar Conference 1997, http:/www.gisqatar.org.qa/conf97/links/m3.html

State of Louisiana, 1995. ACT NO. 922, SENATE BILL NO. 1207, http://www.state.la.us/lgisc/index.htm

State of Mississippi, 1999. Senate Bill 2860, Statewide Scientific Information Management Act of 1999

State of Tennessee, 1999. Request for Proposal for Project Management and Data Conversion Services, Dept. of Finance and Administration, RFP # 317.03.001, October 15, 1999

TGIC, 1999. Geographic Information Framework for Texas, Texas Geographic Information Council, http://www.tgic.state.tx.us