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Implementing GIS-Based Cadastral and Land Information System in Pakistan

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ABSTRACT

The need for information, which is the basic necessity for carrying out any planning, development and management activity, can hardly be over-emphasized. With regard to the developing nations with inadequate resources, the need for having a reliable information base is even more important. The absence of the proper land records in the real land market is another difficulty being faced by many developing countries. The reason may be unclear delimitation of individual or group rights, insecure ownership etc. The necessity for a functioning land market opens the way not only for private development but also for public land acquisition and other means of ensuring that land is available for dwelling and other urban needs. In this way the development and implementation of country-wide digital cadastral information system is an area that needs urgent attention. It is felt that there is a need to at least initiate efforts towards achieving this formidable task in an organised manner. These initial efforts would pave the way to achieve the desired goals in the years to come and would take us out of this status quo situation. With the above background, this paper highlights all the constraints and limitations that will be encountered in the process of integrating legal and geometric cadastral information to develop a new digital cadastral system.

1. INTRODUCTION

Land Information System (LIS) is a tool for legal, administrative and economic decision making as well as an aid for planning and development. This involves on the one hand, the database containing, spatially referenced land related data and on the other hand the procedures and techniques for systematic collection, updating, processing and distribution of the data to the end users in an efficient manner. The base of a land information system is a uniform referencing system that could facilitate in linking the different types of data within the system and with other land related datasets. The most important thing in the land information management is the quantity of the data which can be handled, the speed with which these data can be processed and the ways in which the data can be manipulated and analysed [1].

It is felt throughout the world to move towards the establishment of fully digitized cadastral systems. It is recognised that cadastral systems are not ends in themselves. It is also recognised that the cadastral systems must be tailored to facilitate an efficient land market as well as effective land-use administration and thereby, more generally, promote economic development, social cohesion and sustainable development. Cadastral systems must serve a multi-purpose use and thereby meet the challenge of a modern

GIS and IT environment [2]. The digital land cadastre maintains the official records pertaining to land parcels, their position, shape, size, land use, and ownership. This forms a basis for property taxation that remains one of the main purposes of developing digital land cadastre. The information derived/retrieved from digital cadastral maps can serve administration in many different ways, in addition to contributing to a comprehensive, equitable, and efficient land tax system.

In the light of the evolving digital technology, traditional cadastral maps on paper are not enough flexible and not suitable for the needs of the emerging information society [3]. Moreover, the emerging new satellite technologies enabling earth observation at a spatial resolution of 1m or even 0.61m together with powerful and high speed computing and processing capabilities have completely changed the face of the earth. Similarly, the Geographic Information System (GIS) technology has given a new insight to addressing a variety of resource development, management and planning activities. Without reliable registers, transaction in land is often costly, time consuming, and uncertain. It is normally necessary to establish the fact that the reputed owner and trustee actually have the legal rights to deal with the property. Another difficulty being faced by many developing countries due the absence of the proper land records is the real land market. The reason may be unclear delimitation of individual or group rights, insecure ownership, etc. A cadastral database can remove such obstacles. The necessity for a functioning land market opens the way not only for private development but also for public land acquisition and other means of ensuring that land is available for dwelling and other urban needs.

The traditional/existing LIS in many developing countries especially in Pakistan is entirely based on maps and records on paper formats having no cartographic standards with quite out-dated information [4, 5]. This restricts their operational efficacy in extracting precise information on land parcels, ownership, and taxation as well as planning development activities. While there are a variety of disciplines in which GIS and ICT is being applied, a few of them are of course high priority areas from both operational as well as economic viewpoints. Development and quality improvement of national cadastral and land information system is one such area that needs urgent attention.

2. DIGITAL CADASTRAL MAPPING - SCENARIO IN PAKISTAN

Pakistan, with an area of about 804,000 sq km has different administrative divisions, including; four provinces, namely; Khyber Pakhtunkhwa, Baluchistan, Punjab, and Sindh as well as Federally Administered Tribal Areas. Nearly 70% of the population lives in rural areas, where their livelihood mostly depends on agriculture. Access and rights to land in these areas is an issue of significant importance. However, similar to many other developing countries, the cadastre and land registry systems are one of the weak sectors. Strengthening these systems is a basic necessity and a way of stimulating development process. Some of the significantly important features of these systems include; better information base for planning and administration, better specification of rights in land, more possibilities of finance development, easier implementation of policy measures, and a better steering and control. For implementation of a digital cadastral database, a variety of factors can be taken into consideration as pre-requisites [6]. These factors include the data sources for different land related information, the currently operating land information system and available spatial attribute data as well as the management structure involved in upkeep and maintenance of the land records etc.

2.1. Land information system in Pakistan

It is mentioned earlier that the LIS in Pakistan is based on traditional system of land registers and records that are somewhat complicated, outdated, and quite incompatible to new developments. Besides being quite inefficient, this system of land information has many discrepancies that have created bottlenecks in the development process [7]. The land registry system is under the control of provincial governments in Pakistan, where, no data standards are maintained by different provinces. For example, the size of “Marla”, which is one of the units of land parcel, is not uniform in all provinces. Measurement conventions of property/land parcels are also different in urban and rural areas. However, as far as basic data structure of cadastral and land registry is concerned, both the systems are interlinked and closely associated. The cadastral data includes, Division, District, Tehsil/Taluka, Union Council, Mauza/ Goth/ Village/ Deh, Patwar Halqa, Kanungo Halqa, Khasra/Khewat Number, land feature reference (reference with respect to left/right bank of canals in the area), size of land parcel, and Parcel Identification (PID)/Address. The land registry includes: PID, land category (public/private), registration/mutation number, date of registration/ mutation, lease number, area, encumbrance details, ownership, category (residential, commercial, agricultural, industrial, institutional etc.), owner(s) name and address, land use etc.

The three types of records available are Land Parcel Map, Field Book, and Record of Ownership. The “Land Parcel Map” is the map of all the land parcels that exist in a particular village. This map shows the land parcel ID called “Khasra Number” with dimensions of each Khasra. The “Field Book” is another important data register, which is developed at the time of settlement of land. This information

belongs to the land parcel and provides information about the dimensions of a land parcel; parcel ID (Khasra No.) as well as relation of the ID to the next record set. This record set also contains information about the type of land of that particular parcel of land. The "Record of Ownership" contains information on ownership as well as the historical record of ownership. Additionally, this record set also contains the record of farmer who is ploughing the field. The above-mentioned three record sets are quite compatible with each other as they are developed simultaneously. These records keep on changing with changes in ownership etc, and therefore, need to be updated from time to time.

In Pakistan, after every four years these records are updated.

In the respective local administration, "Patwari" (a govt. official) is a person responsible for keeping information of changes that takes place in these four years. As the "Patwari" is responsible for keeping these record, he updates the splitting and merging of parcels on a cloth map called "Lattha" which is reflection of land parcel map on a piece of cloth that is made of lattha (cotton cloth).

A land parcel map of a Halqa in Khyber Pakhtunkhwa province is shown in Figure 1. The change in ownership is updated in another book known as "Misal Miyadi". The Patwari is also responsible for providing information about the type of crop, which is being grown in any particular parcel of land. This information is collected after every six months and is written in "Register Gardawari".

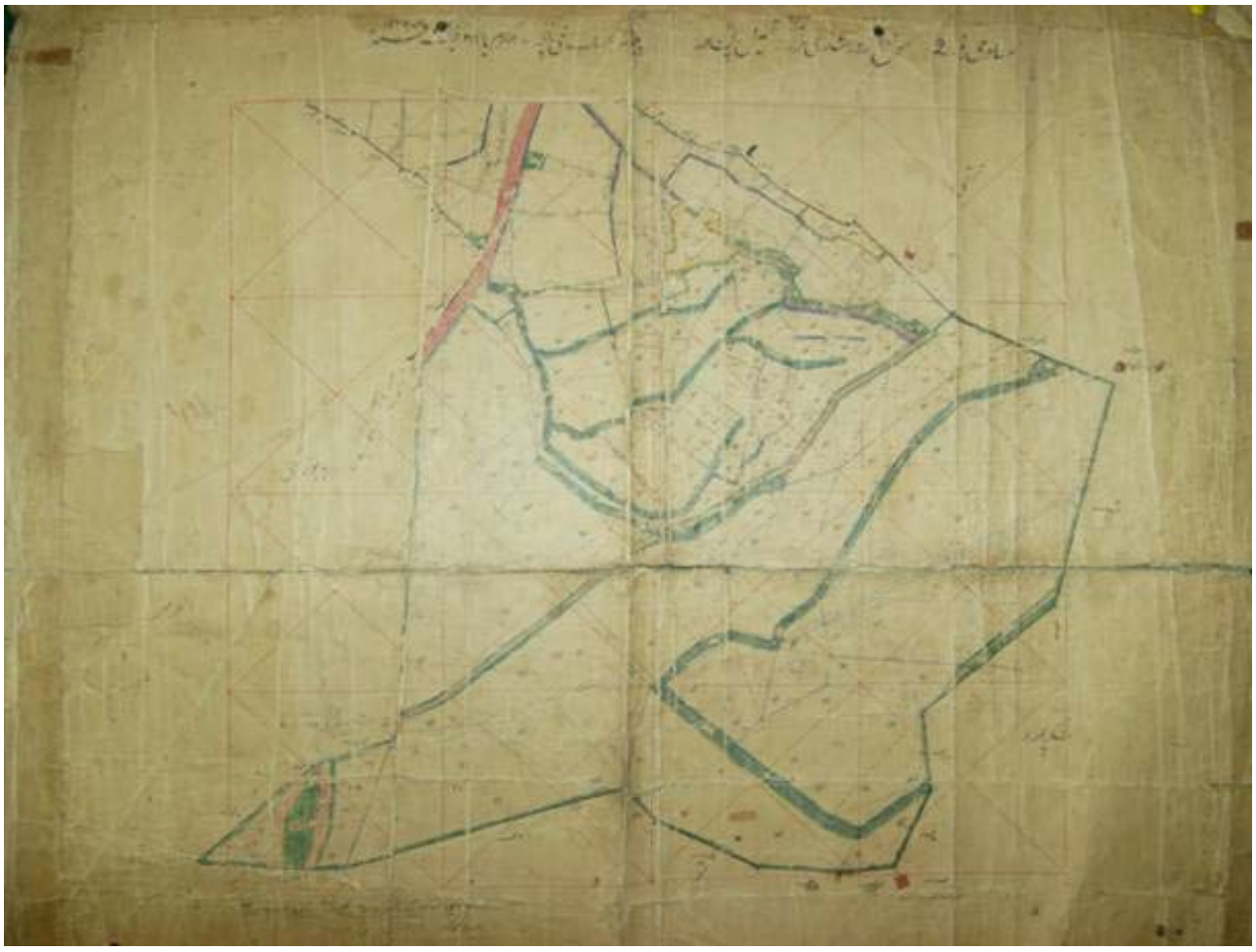

Fig. 1. A land parcel map "Lattha".

2.2. Data sources

A variety of data sources dealing with different data types including topographic maps, land information, social and economic data, statistical records, satellite data/ aerial photographs, and revenue records are operating in the country with specific tasks. For example, Survey of Pakistan (SoP) is responsible for preparing, archiving, updating and maintaining all kinds of topographic maps at varying scales. The Provincial, Divisional, District and Taluka boundaries are also available with SoP. The land and revenue records are maintained by the local administration of provincial departments. The Federal and Provincial

Statistical Departments maintain records of statistical data pertaining to a variety of disciplines such as population, demographic information, housing, health, education, agriculture, forests, water resources, urban, rural areas, communication, public facilities, etc. The satellite data is acquired and archived by the country's national space agency (SUPARCO). The Geological Survey and Soil Survey departments are responsible for their relevant maps and records.

3. IMPLEMENTING GIS-BASED CADASTRAL MAPPING SYSTEM

3.1. Feasibility study

The feasibility of establishing a countrywide cadastral GIS database stems from a thorough understanding and analysis of the needs and the expected benefits/returns from such a database. Also, it involves a clear understanding of the problems being currently faced in the absence of such a system and its future repercussions. It is often observed that the technology developers/vendors oversell the technologies, just highlighting its positive aspects without mentioning anything on its limitations or shortcomings. Under such situation, a user who is not quite well versed in these technologies finds it difficult to assess the real potentials and/or scope of these technologies. A deeper understanding of what a GIS technology can or cannot accomplish is therefore critically important.

An objective need analysis must be carried out in a systematic way by identifying the precise needs of the potential users. The need analysis enables to determine the management approach, identify the mapping and geographic information processing activities, inventory of the mapping resources for both spatial as well as attribute data, evaluate the quality of the data sources, examine the abilities of current staff members, and determine if additional staffing is needed. It determines the training needs, identify the form and content of data sharing among participants, determine the feasibility of GIS development, identify and recommend steps for GIS development if such development is considered feasible.

Under the specific situations, a more detailed analysis may be done, if needed. All the above information acquired in the process of analysing user demands may lead to planning of GIS development, secure development funding, address the base map and hardware/software issues, determine components of the cadastral overlays, design the database, and integrate other relevant components.

While gathering data and assessing users' requirements, it is always important to create a catalogue for adding any new information that supports users' needs study. Based on the users' needs the organisational capacity, manpower, GIS functionalities, data integration, and database requirements may be worked out. When assessing users' requirements, many of the important questions can be answered by a thorough review of the existing LIS being presently used, including parcel maps, land registers etc. For example, the quantity as well as the quality of maps and their scales, the origin of maps, geographic control, symbols, geographic entities, and map updating etc. are all the pertinent information that needs to be gathered.

From users' perspectives, the feasibility study should cover the actual needs, and therefore, the information should be sought from different levels of the users, right from the top policy makers to the functional management. All local codes, laws, and policies that may have any bearing on the needs including the state codes, guidelines, and standards may be taken into consideration.

The needs analysis should consider the time and funds required for training of those involved in the project. Invariably, some training on GIS concepts and hardware/ software systems is needed. The level of training depends on the specific background, education, and experience of each individual on the staff. In most cases, training will be required once a specific software package is selected. Training for specific applications and system management will also be required by the time the system is fully operational. An objective analysis of the precise requirements of both human resources and material is one of the most important components of feasibility study.

An experienced user can envision new and expanded applications of cadastral maps and related attribute data. It is therefore, important to identify the potential applications for which the intended database can or will have to serve during the early stages of GIS planning and development to ensure that the system fulfils the requirements of all those applications.

3.2. Data inputs

As far as spatial data is concerned, in countries like Pakistan, the traditional maps available (a sample map shown in figure 1) are quite old.

These maps are made without any reference grid, and are usually based on some landmarks such as roads, rivers, canals, distributaries etc, wherever available. The physical conditions of the maps are also not very good. Therefore, digitising such maps in their present form would not be quite feasible [8]. However, these maps may serve as a good reference source in producing new maps, either based on any high resolution satellite images from IKONOS or QuickBird, archive of old aerial photographs, or through ground surveys.

This would however depend upon the type of area to be mapped, the scale of the map as well as the

requisite level of details. As far as information contents are concerned, it entirely depends upon the scope of the database, i.e. whether it is to serve the specific purpose of cadastral information or aimed at preparing a multi-purpose cadastral. Similar is the case for attribute information associated with each land parcel.

3.3. Database design

A database is collection of data that can be shared by different users. It is a group of records and files that are organised so that there is a little or no redundancy. So the database enables various methods of data access, storage of data independent of application, control access to data, facilitate data modification, and minimise data redundancy. The data consist of entities and attributes. The entity being a feature that exist, and about which there is specific interest, whereas, the data associated with it may consist of relationship attributes and other characteristics. The attribute is in fact a quality of an entity.

The development of database usually follows a series of process such as; data analysis through which the types and quality of the data to be incorporated in the database is identified. A conceptual model of the data is built by making use of data modelling, taking into account all basic facts and constraints under which the database will have to operate, particularly, the relationship among different entities and their attributes.

The content of the database plays an important role in the overall design of the system and depends upon the sources identified, users and desired applications of the database. Therefore, the size of a database is a function of its content - the more information needed, the larger the database. The database should be designed in such a manner that it takes care of future expansion and adaptability. The feature codes, symbols, and attribute definitions must be determined at the very early stage of the project. In database monitoring, the system is fine tuned and any addition and deletion is implemented.

One of the important components of the entire database system is the database management system. This system is used to control the storage, retrieval, and modification of the data. File handling and file management being one of its functions. It protects the integrity of data and keep track record of each time a system is used, and provides recovery and backup procedures.

3.4. Data coding

The data layers in a cadastral database are organised according to the scope of the digital cadastral maps. For example, in a land information system in a rural area, beside land parcel identification no., the basic attribute information may include, name of the owner, parcel dimension, type of crop (if agriculture), address including; Division, District, Tehsil/Taluka, Union Council, Mauza/Goth/ Village/Deh, Patwar Halqa, Kanungo Halqa, Khasra/Khewat No., Land feature reference (reference with respect to left/right bank of canals in the in the area), land category (Public/Private) Registration/ Mutation No., Date of Registration/ Mutation, details, Lease No., Area, Category (Residential, commercial, agricultural, Industrial, Institutional, etc.), land-use etc.

The data coding can be done through data layers or data coverage, each containing different themes, such as administrative, land use, infrastructure, topography, forest, agriculture etc. The database dictionary can be organised according to coverage description, coverage name, feature class, and theme. For example, the administrative theme contains political boundaries (coverage description), with POLYBNDRY or any other appropriate name as coverage name, polygon and Arc as feature class. A unique naming convention can be set so as to avoid any overlapping among different coverage types within the database. The codes created should be made simple and representative of coverage types. For example, the code for WATER BODY may be WTR_BODY.

The coverage documentation is an important component of the database that contains a schema diagram as well as a table definition form. The schema diagram represents logical relationship between the Feature Attribute Table (FAT) and corresponding data tables. The data table contains a) the name of associated coverage b) feature class such as, polygon, arc, point, c) name of table, Polygon Attribute Table (PAT) or Arc Attribute Table (AAT), d) Data source, the map or documents, where the attributes are stored, and e) Variable is a common name used for variable (items) in the table. A sample snapshot of the parcel information box is shown in Figure 2.

3.5. Organisational requirements

The implementation of a GIS based LIS may involve setting up of an institution or a body entrusted with defined tasks with all the necessary administrative powers to coordinate with different govt. functionaries and come up with a plan of action. This may involve a lot of structural changes in different organisations to be included in various activities in the designing GIS cadastral databases. While some new functions and responsibilities may be added, some of the traditional activities or functions would have to be abandoned or eliminated resulting in change or new responsibilities. In essence, change in procedures; responsibilities, and the computing environment can have profound effects on the structure of an organisation.

Other important legal and organisational issues that may need to be addressed are:

- devising suitable policies for easy access of all necessary datasets for preparation of digital cadastral maps;

- establishing role of private entities and formulating necessary legislation for implementation;

- involving government machinery at different levels and setting up their responsibilities in carrying out the set tasks on regular basis;

- devising policies for community participation in implementation process, if required;

- establishment of a unique parcel identification system across the jurisdiction to ensure that land records are organised appropriately;

- standardisation of address conventions;

- necessary changes in rules and regulations to pass on data among different levels of government and between departments;

- empowerment for decision making at lower levels/functional management of the organisation.

The organisational restructuring would lead to establishing various GIS/database development cells at each ministry and its associated departments, with clear definition of their goals, objectives and time frame for completing specific tasks as assigned by the main body of the frame work from time to time. Each of the GIS/ database development cell will maintain a quality control section, having people with more extensive trainings to generate the quality products conforming to the procedures and standards laid down for each task.

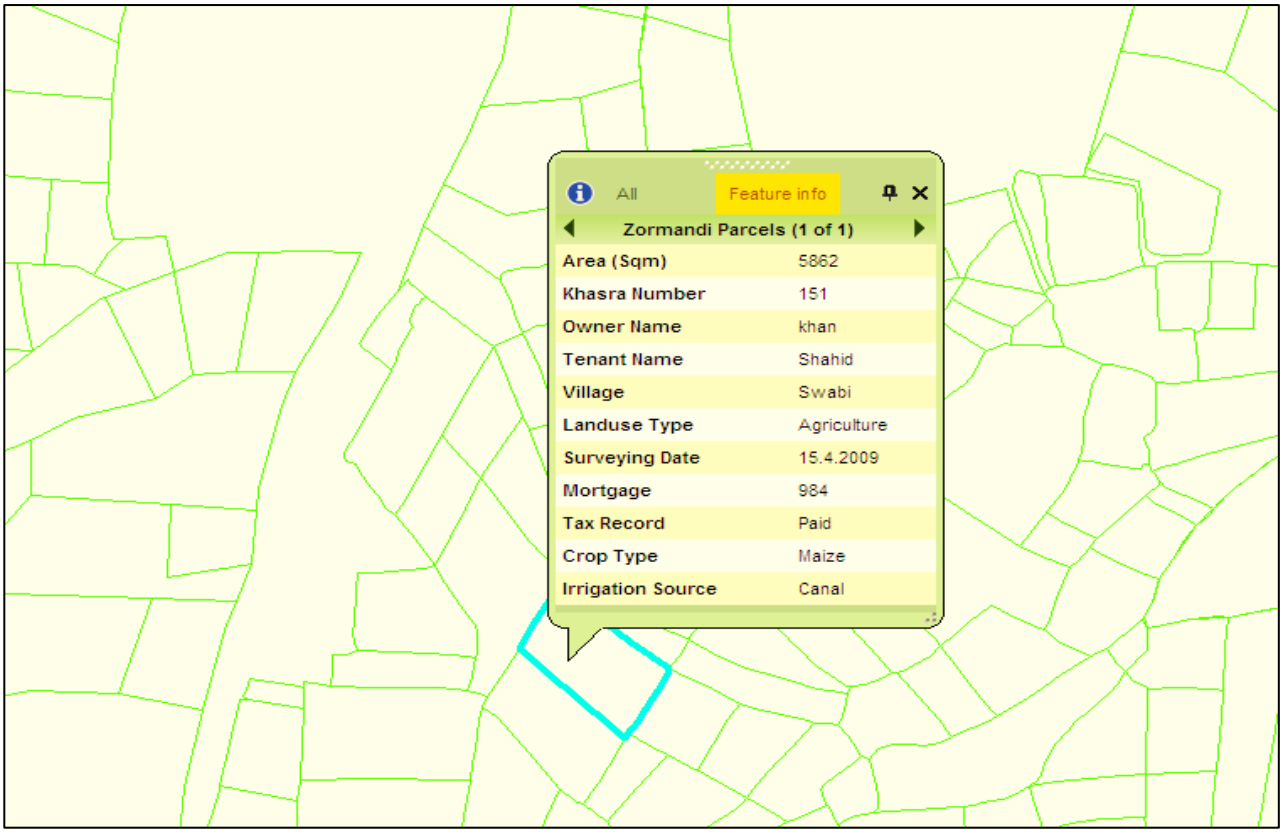

Fig. 2. An overview of information contained in cadastral database.

3.6. Human resource development

GIS technology requires some skills that go beyond traditional assessment and mapping skills. It is important to have people who are capable of performing systems analysis and design, databases management, network administration, and computer operations. It may also be necessary to have staff that possesses skills and experience in cartography, drafting, and even photo interpretation or image processing depending on the applications planned for the system.

Embarking upon such an extensive country wide cadastral mapping project would involve training of manpower at different levels starting from top management, including both technical and managerial, down to the working levels under a chain system. The main body of the framework would be responsible for planning and execution of trainings to be subsequently followed by refresher courses.

The trainings may initially remain the responsibility of the main body of the organisational framework, and later can be transferred or distributed at local level.

Challenges in setting up cadastral database

The main purpose of the cadastral database is to keep record of all land parcels and their ownership,

so as to form an accurate transparent and efficient system for property taxation.

The use of GIS technology offers a possibility to keep positional data in digital form and to connect them with a variety of attribute data to be used as and when needed.

It includes spatial information and facilitates performing spatial analyses that provide new derivative information about the various parameters pertaining to different entities.

The GIS technology has expanded to economic and social information systems that carry great potential in a host of discipline areas.

The main idea that is followed is to develop a system organised into different layers, with the same rules for each of them (the functional model is the same for all layers).

The specific problems of a particular layer need further solutions. While GIS is no doubt a very flexible tool for handling land information and its management in a much efficient manner, but this technology is confronted with a lot of challenges in operational utilisation, particularly in the developing nations.

Of course, these challenges are not entirely related to technology; rather, there are a variety of other factors, which are only relevant to local problems of the respective countries.

As far as GIS technologies are concerned, these are in fact been in operation in several countries, where all the data inputs are available and have already been converted to the requisite formats.

Those countries are now drawing benefits of this technology for the past several years.

Some of the problems identified and the challenges being faced by the developing countries in operational implementation of these technologies include:

- lack of awareness about the technology;
- absence of a framework for undertaking GIS implementation task;
- a momentous task of converting traditional datasets (GIS inputs) in to new forms;
- inadequate resources;
- inaccessibility to different data types;
- lack of trained manpower;
- non availability of requisite administrative structure;
- fixing of land parcel boundaries in the new system etc.

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