REQUIREMENTS ANALYSIS FOR DEVELOPING A NATIONAL GIS INFRASTRUCTURE FOR TRINIDAD AND TOBOGO

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ABSTRACT

Geographic Information Systems (GIS) provide a better storage and distribution mechanism for spatial data than the classical hardcopy map, hence, the growing increase in the demand for a national or corporate approach to its development. A national GIS will serve the spatial data needs of several public and private agencies to meet their various land management activities. The development of a national GIS, however, hinges on the existence and continual maintenance of three basic infrastructure elements: data, technology and institutions. This paper analyses elements of this infrastructure vis-a-vis requirements for the establishment of a national GIS in Trinidad and Tobago.

1.0 ABSTRACT

Geographic information systems (GIS) are computerised information systems that are designed to capture, edit, store, retrieve, process and disseminate spatial and attribute data which are referenced to some predefined geographic/geodetic referencing systems. The superior data handling and data processing capabilities of GIS are responsible for the increasing adaptation of the system in varying field of applications. Its application to real-life phenomena is widely growing and is currently cut across professional barriers. Almost all life phenomena that has spatial relationship can be conceived to benefit from GIS functionalities.

The adoption of GIS concepts and technology for the management and analysis of spatial features is on the rise in Trinidad and Tobago. In the last four years, GIS technology has been acquired by eight agencies. Three agencies: the Water and Sewerage Authority (WASA), Trinidad and Tobago Electricity Company (T&TEC), and the Town and Country Planning Division (TCPD) have operational GIS running on UNIX workstation platforms. The total cost of investment in terms of hardware, software, training and data acquisition is estimated to be over TT$10 million. It is heartening to see the growth in the adoption of this technology. However, it is disheartening to note a lack of coordination and comprehensive development strategy for the adoption of GIS technology. For a "small", unitary country like Trinidad and Tobago, a national proactive strategy is required for the optimum use of GIS. The present approach, which can only be described as "piece-meal" or "proprietary", could lead to duplication and would not facilitate the attainment of the benefits of a national GIS as listed in **Table 1.**

a.	Reduction in duplication with regards to data collection and data storage.
b.	Ensuring compatibility in spatial analysis among agencies.
c.	Improving efficiency in data management across agencies.
d.	Increasing accessibility to relevant data.
e.	Improving decision-making process especially in land-related activities.

Table 1: **Benefits of a National GIS**

The need to develop a national strategy is partly to satisfy the needs for land-related data of potential GIS-user agencies in Trinidad and Tobago (as listed in **Table 2**). The majority of these agencies are not traditional map users, but some of their activities involve the use of land-related data and spatial analyses. A national proactive strategy will not only lead to reduction in investment cost but will also prevent mistakes and errors associated with the use and development of GIS. The successful development of such a strategy, however, hinges on the existence and maintenance of three information technology infrastructure elements: data, technology and

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Land Use Administration Sectors	Natural Resources Management Sector	Infrastructure Development Sector
Town and Country Planning Division	Ministry of Energy	T&TEC
Valuation Division	Ministry of Agriculture	TSTT
Land Registry	Forestry Division	Highways Division
District Revenue Office	Fisheries Division	Water and Sewerage Authority
National Housing Authority	Caroni (1975) Limited	Drainage Division
Election and Boundary Commission	Petrotrin	Police Service
Central Statistics Office	Tourism/IDC	Ministry of Education
	National Petroleum	Ministry of Health
	Institute of Marine Affairs	Ministry of National Security
	Water Resources Agency	Commercial Banks

Table 2: **Potential Users of NGIS in Trinidad and Tobago**

institutions, as shown in **Figure 1.**

The adoption of a national approach to the development of GIS is not new in the developing countries (Taylor, 1991). In Trinidad and Tobago, efforts have been made by land administration agencies (Lands and Surveys Division, Valuation Division, and Town and Country Planning Division) to develop some form of infrastructure e.g., the attempt to develop a National Data Bank in 1976; the development of a new National Administrative Grid in 1987; the development of a Land Administration and Policy in 1989; and recently the formation of a committee on GIS policy for Trinidad and Tobago in 1993. These efforts indicate an appreciation by the initiators, of the need for a national strategy and the willingness to collaborate and provide one. However, the results of these efforts are inadequate to meet the new challenges required of a corporate computer-based NGIS. The failures of these efforts can partly be attributed to the following:

a. inadequate funding,
b. lack of continuity in the implementation of new and workable concepts,
c. lack of coherent development framework, and
d. lack of political support.

2.0 DATA REQUIREMENTS

The importance of data in GIS cannot be over emphasised. Data is used to generate GIS applications. The scope and depth of a GIS are related to the variety and magnitude of data readily available to the system. The quality and currency of the data also determine the integrity of information products generated by the system. The acquisition and maintenance of data required to satisfy specific purposes of GIS investment are major undertakings which cost money and time. Hence, data acquisition should be properly planned and managed. The following characteristics of land-related data should be considered: data needs analysis, data acquisition systems, and data management requirements.

2.1 Data Needs Analysis

The first step in the development of a National GIS is the understanding of the potential users of the system and their various data needs. Such understanding can be acquired through a User Requirements Study (URS), which is conducted throughout the country, involving land-related agencies in both public and private sectors. The study would investigate the functions of these agencies vis-a-vis the spatial data required to perform those functions. Apart from identifying this data, the current sources of the data, the frequency of use, the data format, and the costs of acquisition and

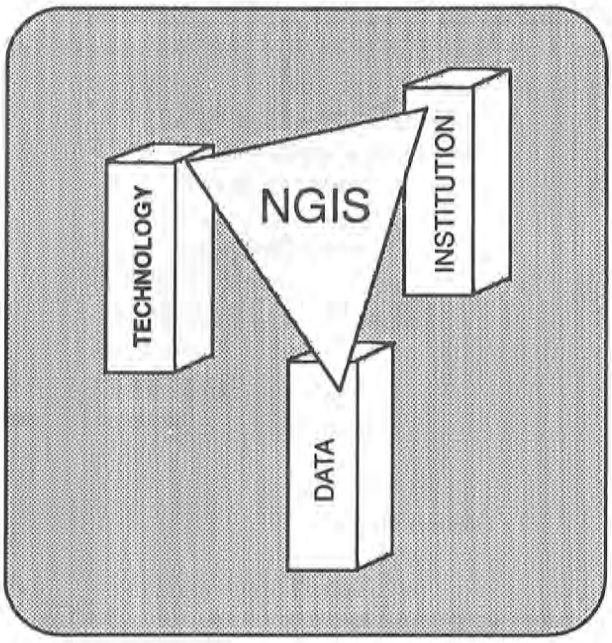

Figure 1: **The Infrastructure for a National GIS**

management should all be determined. The information products generated from the use of the data and the list of agencies to which these products are distributed should also be identified. The result of such a study would lead to an understanding of the data demands of each agency, the identification of any duplication in data collection, and the description of the characteristics of each data item. Deficiencies in data collection and management should also be analysed. Questionnaires, selected interviews and workshops are efficient tools for undertaking such studies. A period of approximately two-to-three months would be required to complete such studies in Trinidad and Tobago.

2.2 Data Acquisition Systems

A knowledge-based decision on land management would rely on the availability of accurate and current land-related data. The apparent high capital cost of collecting and managing these data is the major deterrent to its availability. However, this cost, if evaluated against the multiple usage of the data (especially in a computerised environment), is insignificant when considered in the wider context of national physical development. In the last two decades, technological development has improved the collection of land-related data (spatial data) through the use of Global Positioning Systems (used to acquire geodetic position of features), digital photogrammetry and remote sensing imagery. These computer-intensive data acquisition systems have two significant consequences: reductions in time and cost of data collection. Though they have high capital cost in relation to the economic needs of developing countries, their unit costs in a corporate environment is relatively low.

The accuracy and resolution of data are sensitive issues in developing a NGIS. They are directly linked to the cost and degree of utility of the system. Depending on the data acquisition system used, the accuracy and resolution of the data collected should meet the requirements of a large section of the community of users. Users of land-related data have the tendency to ignore data of lower accuracy and lower resolution. In order to meet the needs of the users, the accuracy and resolution requirements of each agency should be determined and considered when selecting the data acquisition system. In developing a road network database, for instance, the level of accuracy and resolution chosen can greatly impact on the level of utility by the national community of users.

2.3 Data Management Requirements

Land-related data should be maintained and managed, not only because of the "high" cost of its initial acquisition, but also to ensure that they provide adequate information products for specific applications. Data management requirements entail developing mechanisms, strategies and procedures for the following data management activities:

a) Updating mechanism
b) Storage and retrieval mechanisms
c) Data definition and dictionary systems
d) Data integration strategy
e) Data evaluation procedure

2.3.1 Updating Mechanism

A mechanism for periodically updating data should be developed and funding options identified, to ensure that the data is relatively current. Features such as roads, rivers, soils, and contours may require a much longer updating cycle compared to buildings, property boundaries, coast lines and land use. While photogrammetric methods can be used to collect baseline data, the use of remote sensing method should be explored to update the data.

2.3.2 Storage and Retrieval Mechanisms

Inefficient data storage and retrieval mechanisms can result in underutilisation of data. For example, the large

HARDWARE COMPONENTS

Input Devices	Output Devices
Digitisers	Printers
Scanners	Plotters
Dataloggers	Video Display Terminal
Computing Platforms	**Storage Devices**
Micro-computers	Optical Disk
Mini-computers	Magnetic Disk
Mainframe computers	Digital Tape Cartiridges

Telecommunication Devices
Network Servers
Bridges and Gateways
Communication Media

SOFTWARE COMPONENTS

Operating Systems	Database Management Systems
Raster-based Software	Vector-based Software
Object-oriented Software	

Table 3: **Examples of Technological Components for a National GIS.**

volume of books and folios being kept at the Vault of the Land Registry is not fully used to obtain real property information, due to its storage in books and its retrieval through the names of grantee/grantor. Thus, a typical information search may last one full-working day. A national GIS must provide for efficient data storage and retrieval mechanisms so as to accommodate concurrent access by the wide community of users while ensuring security and integrity.

2.3.3 Data Definition and Dictionary Systems

Developing a national land-related database to support various developmental activities is an enormous program. The wide variety of land-related data which will be collected and managed require that each data item be properly identified and defined. The differences between rivers and streams, roads and highways, houses and apartments, and towns and villages, for example, should be properly defined. The agency officially designated to collect and manage specific data items should also be known to all potential users. The mode of collection, format of storage, accuracy and resolution of each data item must be properly documented in a data dictionary. Such a dictionary is the first "*port of call*" to users of a national GIS, for it gives a synopsis of each data item being managed. The existence of a data dictionary for the entire system would reduce duplication in data collection and facilitate access to data. Such a dictionary is one of the outputs of a user requirements study.

2.3.4 Data Integration Strategy

The task of developing a national GIS does not imply that data will be acquired using a simple data acquisition system and at a fixed or uniform resolution. Multiple acquisition systems and resolution can be adopted, as long as its adoption can be justified and "*paid for*" by the users. The resolution of widely used data would rarely be uniform throughout the Islands. A national GIS must therefore provide strategies for the integration of data from different sources, different resolutions, and different projections and datums. By displaying such flexibility, the system will be able to attract a larger community of users.

2.3.5 Data Evaluation Procedure

One major virtue of a corporate database required by a national GIS is integrity. The users of the system must have confidence that the data accurately depicts reality. A certain level of trust in the accuracy of the data must be evident. It is thus, the task of each data-collecting agency, to ensure that each item of data is adequately evaluated and its correctness guaranteed before it is entered into the national database. Such quality control will lead to increase utilisation of the database. Error-reporting procedures as well as strategies for adding and deleting data items should be designed and implemented throughout the life-cycle of the database.

Developing a corporate database to support a national GIS is a major task which requires interdepartmental collaboration. It also requires expertise. A model of the typical data layers and application categories required in a national GIS is illustrated in **Figure 2.** The land-related databases are the different categories of data required. Since these data are collected on a common spatial referencing geodetic framework, it will be possible to overlay and integrate them for specific purposes. The database can be used for five main categories of functions: mapping, measurements, management, modelling, and monitoring of the natural environment.

3.0 TECHNOLOGICAL REQUIREMENTS

Recent developments in information technology are providing major infrastructure required for the building of a national GIS. These developments have encouraged and improved the multiple and concurrent use of data, facilitated data sharing and provided security to data. The use of these technologies and their integration requires proper planning.

3.1 Technological Components

Technological components can be divided into two categories: Hardware and Software. Hardware consists of devices which can be used to undertake the following functions: data input, data processing, data storage, data output and data dissemination. A listing of these components is provided in **Table 3.** Depending of the format of the spatial data, data input can be achieved using digitisers or scanners for hardcopy maps. Aerial photographs and other terrestrial photographs can be scanned using a high resolution (300 dpi or higher) and medium format scanner (20" x 10" or larger). Attribute data can be entered directly using the computer keyboard or via a data logger. Land surveying data as well as GPS data can be downloaded into a computer for pre- and post-processing.

Data processing is undertaken by the computing devices. The Central Processing Unit (CPU) and the main memory of the computer are the core elements of the computer. The design features of the computing device relevant to a NGIS are: processing speed; storage capacity of the main memory; the operating system; and its portability. The adequacy of these features should be evaluated against future data-processing demands. The ability to integrate micro-computers, minicomputers and mainframe computers is a major consideration especially when there is the need to efficiently utilise existing computers.

The storage of data in digital formats has proven to be more economical in terms of reduction in storage space and ease of retrieval. The magnetic tape is the oldest secondary storage medium and one of the least expensive. It is a stable storage medium and it is used when large amounts of data must be stored at very low cost. Its main disadvantage is that data retrieval is very slow. The magnetic disk is more modern. It permits direct and immediate access to data. It is available on the computer as a hard disk and as a removable floppy disk and cartridges. The optical disk is the most modern device. Data are recorded and read by laser beams and it has greater density than the magnetic disk. The design factor in the selection of data storage devices are: storage capacity, stability of medium, access speed and cost.

There are varieties of data output devices. Printer devices ranges from dot-matrix printer, laser printers, ink-jet to thermal-transfer printers for graphics. Plotters are the most preferable medium for the production of large format hardcopy graphic outputs. The variety of plotters range from the line-plotter, ink-jet plotter and electrostatic plotters. When there is no need for a hardcopy output, the video display graphic terminal is the most appropriate device. It is used for interactive design of hardcopy maps. The resolution and colour capability of the graphic terminal is very important as well as its ergonometric quality.

The ability to send and receive data across a network of computers, irrespective of the distance is a major development in information technology. Electronic data dissemination leads to reduction in data duplication and would result in data consistency across agencies. The use of Wide Area Networks (WAN) and Local Area Networks (LAN) are improving the ability to link the various units of a department internally and externally with other regional or international agencies. The architecture, protocol and topology of these networks should be designed after considering the institutional arrangements between agencies. A study of user requirements would provide an indication of the type, direction, and volume of traffic.

Software comprises the detailed instruction or programmes that control the operation of computers and its peripherals. The software required for an NGIS consists of: the operating system e.g., DOS, OS/2, UNIX; application GIS e.g., raster, vector, object-oriented, or hybrid-based; database management systems e.g., ORACLE, dBASE; and communication software. The operating system manages the input/output of instructions into the computer hardware. Application GIS software is the core software that performs the various spatial analyses and mapping required by users. Database management systems (DBMS) assist the GIS software in the handling and manipulation of the large volume of data required. Communication software provides the means and protocols for requesting, sending and receiving data across the network of users. The choice of software requires an understanding of the nature of GIS applications required by the user community. The major challenge is ensuring compatibility and portability.

3.2 Technological Issues

Technological requirements for developing an NGIS in Trinidad and Tobago pose the following challenges as it does in most other developing countries: costs; support services and training. Despite the continued reduction in the prices of computer hardware and software, these prices are still relatively prohibitive to a small developing country and are threatened by possible increase in the foreign exchange rate of the country. In the face of competing social and health requirements, expenditure on information technology is often difficult to justify. The availability in close proximity of support services required for the repairs and maintenance of information technology is also a concern. The non-payment of support services fees and/or the lack of such services could lead to abandonment after a minor problem. Training in the use of software and development of user interfaces are challenges posed by availability of trainers and the cost of training. In order to efficiently utilise computer hardware and software, trained personnel who understand not only the usage but also the design concepts are required. The ability to retain these personnel after expending a high training cost is another issue facing public agencies in particular. A national strategy on the procurement, use and maintenance of information technology is generally required.

4.0 INSTITUTIONAL REQUIREMENTS

An efficient and effective national GIS relies on the existence and adequacy of an institutional structure, which provide for rules, regulation and procedures for the development and use of the system. There must be order in the way things are handled and authority vis-a-vis responsibility must be provided to competent officials. Data and technology on their own cannot provide the valuable information products without adequate human interactions. There are four main institutional requirements which must be developed and maintained: standards; administrative mechanisms; legal considerations; and financial considerations.

4.1. Standards

One main attraction of computer technology is the ease of data sharing across agencies. Depending on the data networking configuration, data items collected by one agency can be shared with other authorised users or agencies. The ability to share data and other resources is dependent of the existence and maintenance of GIS standards. Standards facilitate portability of application from one computer hardware platform to another and data distribution across agencies (Tom, 1990; Exler, 1990).

Coleman and McLaughlin (1992) provided a taxonomy of standards required in a corporate national GIS (**Figure 3**). The taxonomy identified four overlapping main categories: hardware and communication; software; data specifications and formats; and data sets. Whereas hardware, communications and software standards can be adopted, for they are mostly influenced by the industry, data specifications, data formats and data sets standards are local domain decisions which each country must fully study and develop by themselves. They provide specifications for data models, data quality, data layers and associated attributes, data exchange formats, map projection and geodetic datum, cartographic representation of features and the like.

The task of developing and implementing GIS standards require a collaborative effort of all major GIS-user agencies in the country. In addition, it requires political and financial support to encourage compliance. Standards on their own cannot drive GIS development. They should thus accommodate rather than restrict, encourage rather than frustrate; and integrate rather than discriminate among potential users of the system.

4.2 Administrative Mechanisms

The multiplicity of users and data layers associated with the development of a national GIS require that procedures, authorities and responsibilities be assigned to individuals or agencies. These would provide order into the operation of the system and ensure checks and balances. Administrative mechanisms should, for all practical purposes, facilitate rather than become a bureaucratic "*bottleneck*" to the operation of the system. Due to the sensitive nature of land-related data vis-a-vis its use in national physical and economic development planning, as well as the "*high*" capital costs of its acquisition and management, a National Land Information Council (NLIC) should be constituted. The membership of the NLIC should comprise the Ministers of leading land-related agencies, such as the Ministry of Planning and Development, Ministry of Works, Ministry of Agriculture Lands and Marine Resources, Ministry of Energy and Energy Industries and Ministry of Public Utilities. The role of the Council should be to formulate operational and financial strategies for the efficient management of the system, as well as to allocate responsibilities to agencies. The Council should report directly to the Cabinet. The NLIC should be served by a GIS Advisory Committee (GISAC). The

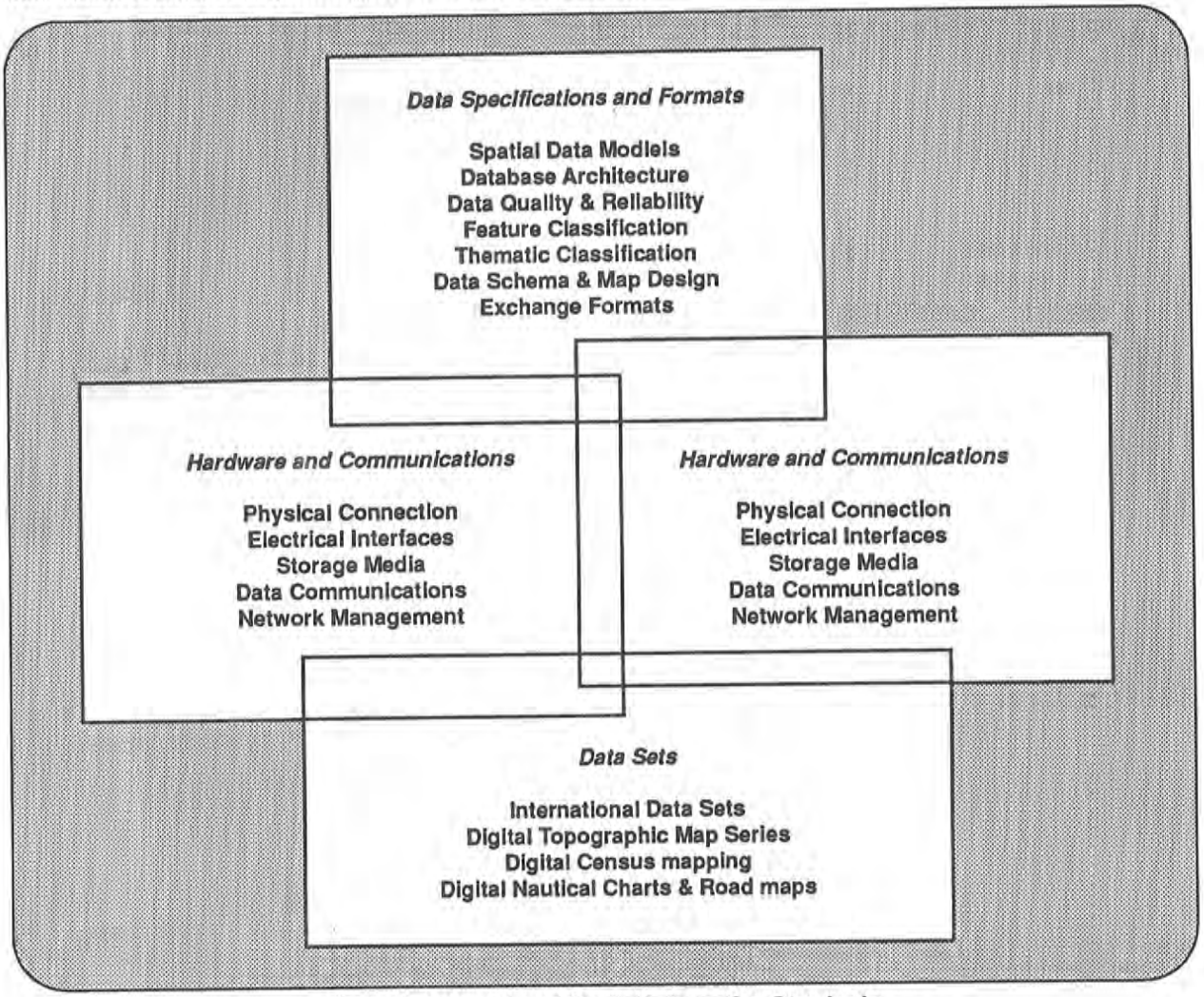

Figure 3: Categories of Spatial Information Standards (Coleman and McLaughlin, 1992)

GISAC should comprise representatives of major GIS user public agencies, leading private sector GIS developers and individuals with proven technical knowledge of any components of GIS. The GISAC should be the technical arm of the NLIC. Its role should include advising the NLIC on technical and managerial aspects of a national GIS. As part of its operation, the GISAC should be able to undertake or commission studies, research and benchmarks to validate propositions. The GISAC would seek alternatives and its findings are to be sent to the NLIC for final decision. The NLIC may solicit advice on any matter, from other sources apart from the GISAC, as it deems fit. The user community is the driving force behind the development of a national GIS. Its collective views and responsiveness to GIS issues should be adequately addressed by the NLIC. Typical responsibilities of the NLIC are listed in Table 4.

Administrative mechanisms must be developed for distribution of data and information products by the collecting agencies. Auditing procedures are also required to provide a knowledge of who the users are and what applications are used, as well as the frequency of usage for each data item. The audit report will be invaluable for the management of the system.

4.3 Legal Considerations

Legal considerations of corporate databases are currently attracting attention especially in the developed countries. Legal issues to be considered include access, privacy, ownership and liability. Even though a global and corporate system are being developed, access to the content of the database needs to be controlled or regulated. Such control should, however, be in line with other constitutional rights e.g., "freedom of information". This has become important

especially, when personal and/or fiscal data are being collected in respect to real properties and agricultural lands. Levels of access must be provided for different categories of persons and agencies. The right of privacy of the citizen should also be respected to the extent guaranteed by the Constitution. Ownership of the data collected by the various agencies implies responsibilities with regard to the accuracy and currency of the data. If the unsuspecting user of the data suffers due to errors or inadequacies, the data-collecting agency might be liable for the losses. The whole range of legal implications in the process of data dissemination should be fully studied to safeguard both the users and the data-collecting agencies.

4.4 Financial Considerations

Developing a national GIS requires a high capital cost, moreso, the management of the system. Continuous funding is required for the development and improvement of the system (Ottoson and Rystedt, 1991). With the current decline in the economy of the country, alternative sources of funding must be explored. The sales of information products generated from the systems are becoming an alternative source of funding. The culture of "*freeness*" should be curbed especially since it costs money to collect, store, process and distribute the data. The question of sales of data centres around the problem of pricing computerised data. For example, the current fees being charged by the Lands and Surveys Division for hardcopy maps are grossly inadequate to meet the cost of maintenance of the maps. The Water and Sewerage Authority's scale of fees for land-related data, though novel, can hardly support maintenance cost. There are five concepts to pricing policy: management cost recovery, market value pricing and direct cost of distribution. The appropriateness of each of these concepts should be adequately investigated.

5.0 CONCLUSION

The development and maintenance of the three basic infrastructure for a national GIS is vital not only to ensure that investments in GIS yield optimum results, but also to provide order in the whole business of national physical planning. Existing infrastructure should be upgraded to meet the new challenges. Human resource training and in particular retraining should be evaluated against the three infrastructure. The Government of Trinidad and Tobago should take a more proactive role in the development of these infrastructure through direct

- Decision-making body.
- Formulate operational strategies.
- Identify and seek financial assistance.
- Allocate resources and responsibilities.
- Develop land information policy.
- Ensure accountability.

Table 4: **Responsibilities of the NLIC**

capital funding and the establishment of institutional structure required to manage an NGIS. In addition, the various agencies in particular, Lands and Surveys Division, Water and Sewerage Authority, Town and Country Planning Division, Valuation Division should develop a coordinated approach to the sharing of data and resources.

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