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FRAMEWORK OF BASIC CONDITIONS AND GUIDELINES FOR THE ESTABLISHMENT OF A NATIONAL RESOURCE AND ENVIRONMENTAL GEOGRAPHIC INFORMATION SYSTEM.

INTRODUCTION

1. GIS has become the new creed for all those who deal, in one way or another, with land resource development, environment protection and all other activities related to land occurrences. This phenomena, is, to a great extent, a result of the power of these systems to cope with increasing amounts of spatial information of different type and its ability and flexibility to process and display the data according to different uses and planning scenarios. It can also be misleading to those who want a GIS to solve all their problems. Some planners may feel that GIS must be introduced at any cost and without delay in their operations, without fully understanding all the implications of establishing a GIS, mush less the kind of GIS that is suitable to them. Surrounded by an overwhelming amount of GIS-promoted software available, ranging from complex and expensive to the simpler and the cheap, many organizations are tempted to purchase one particular software and begin collecting digital data, often on ad-hoc basis, in the belief that they are establishing the GIS they need. Within a region, a country, a municipality or even within an institution, a proliferation of ill-suited GISs will most likely result in nothing more than a lamentable waste of resources.

2. On the other hand, many may be reluctant to enter GIS for fear of getting involved in something that is too technical, too costly, implies too much work and is not worth it.

3. When these two attitudes --the positive-but-naive and the negative-- persist, the high front-end costs coupled with confusion and frustration will by far outweigh any gains, and what initially were dreams and expectations turn into nightmares. The results rather than beneficial will prove damaging and may delay or destroy any further attempts to use this new technology.

4. In order to avert these situations, GIS developers, producers, scholars and users, usually from the private sector, have generated various models providing rules and guidelines on how to construct a GIS. However, they are part of the scientific literature and are "promulgated" in specialized publications, dispersed among or entwined with technical articles of all sort, and do not the reach the normal planner. This paper intends to compile, reconcile and integrate many schemes proposed by renowned scientists and specialists.

5. There is no general model that suits every country for the establishment of a national geographic information system, as there is no general set of procedures or steps to implement such a system. These is a large range of conceptual models and implementing procedures among which to choose to better satisfy the needs and peculiarities of each individual country. However, a number of basic enabling conditions and guidelines are identifiable as being crucial to the success of building up a useful geographic information infrastructure in any country. These exist at both national level and institutional level. An attempt is made here to provide those that are thought of major relevance.

AT NATIONAL LEVEL

Understanding of modern information technologies and their potentials by those who have the keys to development

6. It is essential a full understanding of the potential of modern information technologies, in particular geomatics, and of the ***need*** to use then in the inventorying, assessment and management of natural resources and the environment, and in setting up and steering sustainable development paths that will solve socio-economic problems of African countries, all urgent and overwhelming.

7. It must be realized that the possession of a reliable and efficient spatial information infrastructure is as important as other national infrastructures upon which the governments concentrate their efforts, such as health, education, transport, energy, etc. Making a parallel, what expectations could have an international airline without possessing a reservation database server or that is not linked to the global reservation network?. How could a modern bank presently operate without possessing a client/account information system networked with its branches and subsidiaries?.

8. Such an understanding must be done at the highest levels among planners, decision and policy makers, in the government (heads of state, ministers, etc.), in the political scenario (chiefs of political parties, senators, in some cases governors and majors, local community leaders, etc.), in the production and industry sectors, etc.

The appreciation for base-line spatial data and information

9. Base-line data and information, in particular topographic and other land information maps, is normally the least appreciated tool. National mapping programmes, which in the past were at the forefront of development, are nowadays given little preeminence in national development programmes. As a consequence, the cartographic coverage of the majority of African countries, with some notable exceptions, is deficient and outmoded, in some areas nonexistent or the mapping is only planimetric, and in others little attention was given to geodetic control. Although valuable efforts have been made by some leading countries, the situation for many of them remains unchanged and may worsen as time elapses. The governments must grant to this activity a high priority, allocating the resources that it needs to complete, improve and maintain their national cartographic coverage. Otherwise, their efforts to build any national geoinformation infrastructure will be futile, and whatever is done will lead only to a lamentable waste of resources and an anthology of frustrations. Simply, a building without foundations cannot be erected.

The will and commitment to change

10. Understanding potentials and realizing needs is not enough. It is necessary to have the commitment to change, by conviction. Only then we can expect to practically materialize this change. This commitment has to be a long-term commitment. It has to last at least until the development of the system is well in place, and its benefits appear. Then the users (among which the government will be the major one) will be the driving force to maintain and continuously

expand the system that may become self-sustainable.

The materialization of the will to change: A Plan of Action (or the implementation of Agenda 21)

11. A plan of action, issued at the highest level, that would lead to a national programme for the creation and management of a geographic information system, would be the first step to materialize the will to change. Such a Plan of Action would reflect nothing else than implementation of important components of chapter 40 of Agenda 21. A copy of this agenda appears as Appendix 2. This plan of action can (should) initially be simple. It would, at further stages and as results of its own implementation, be amended and improved, going in deeper detail, changing strategies and procedures, adding new components, fixing new responsibilities, etc.

12. This initial plan of action would:

(i) provide principles on flow, access and supply of geographic information.

(ii) define the goals at short, medium and long-term.

(iii) identify the sectors that would be addressed by the system: principal, secondary, tertiary.

(iv) identify the actors including those of the private sector: national and sub-national agencies, research and educational institutions, agricultural and livestock associations, scientific and professional associations, etc.

(v) create a national steering body, constituted by a core set of actors, including the private sector, with the task of defining the nature, characteristics of the system as the methodology, procedures and time-frames of implementation. When necessary, any other members can be coopted by the steering body. This body would be accountable to the highest levels of government, to which it would report regularly at specific intervals.

(vi) Define provisional budgets and budget lines.

A National steering body on geomatics:

13. It can be an ad-hoc Committee or a permanent Council. Sometimes, a leading Institution may be selected to coordinate the work of the Committee or Council. Its work would mainly be conducted by working groups, whose initial functions would be:

(i) Identify the spatial datasets that are required for each sector or aspect of development. This exercise will necessarily comprise the identification of data users, data needs and data sources, required data accuracy, as well as the selection and prioritization of scales.

14. In general, the following datasets have been accepted as an appropriate basic set for national planning.

Fundamental data sets:	(a)	Topographic map: geodetic control elevation (DTM) water areas, drainage and shorelines terrestrial communication lines cultural elements general vegetation: forests, rangeland, cultivated areas and pastures. principal administrative boundaries
Other data sets	(b)	baseline satellite image
	(c)	cadastre, land tenure, detailed administrative boundaries.
	(d)	geology/mining
	(e)	land use/land cover
	(f)	soils and land vocation
	(g)	energy
	(h)	restrictive sites (public lands, special tenures)
	(i)	climate
	(j)	fauna species distribution

15. It is very important to bear in mind that the topographic map is the basis upon which the other datasets are geometrically fit. ***Hence, it must have the highest priority.***

(i) Compile a classified catalogue of all existing data and information that is deemed relevant, assessing the attributes of each piece of information. The committee will also be responsible for assuring that such metadatabase is properly maintained.

(ii) Identify data gaps, and provide concrete recommendations for new data collection.

(iii) Select the model of the national geographic information system (central database, distributed database, combined central and distributed) and, accordingly, how the different datasets are organized.

(iv) Compile an inventory of all existing hardware and software, within participating parties, qualifying its relevance to the project: operating platforms, capacity, compatibility, risk of out-datedness, flexibility, facility of maintenance, possibility to expand, etc.

(v) Analyze the current mandates of the different participating institutions. The Committee would agree on new limits to the mandates for the purposes of the establishment of the national geographic information system, in order to avoid the normal conflicts due to overlapping and duplication, or to fill gaps, that inevitably will always be found. Precise responsibilities and roles of each institution would be clearly defined within the system, so that every actor knows what to do and what to expect without ambiguities.

(vi) In the light of the above, the Committee would propose or set up the rules, as applicable, concerning legal and technical aspects of mandates, proprietary rights, security and confidentiality, flow of information, access and supply, pricing of the information, data quality standards and standards for data collection, data up-dating, data conversion, integrity and integration of datasets (geometric, data transfer, etc.)

(vii) At least a written master agreement is necessary to protect the interest of all parties to the extent possible, where the issues in (vi) and (vii) above are clearly defined.

(viii) Provide advice on and revise the data models and data structures proposed by each institution for the datasets of which it is responsible for producing and maintaining, verifying that they satisfy the needs of all the development sectors that will use those datasets.

(ix) Revise the necessities and procurement of new equipment and software, assuring that there is full compatibility with the equipment and software of the other participants of the systems, and that appropriate existing equipment and software has maximum, but reasonable, possible utilization.

(x) Design and coordinate the execution of pilot studies and pilot projects, where tests of small integrated systems would be carried out as a means of obtaining practical experience with the technology and its possibilities, and test system conditionalities such as networking and communication among GIS sub-systems, standards, database export-import, data integrity, data flow, etc.

(xi) Propose, set up and phase implementation plans.

AT INSTITUTIONAL LEVEL

Variety of databases and GIS within the system:

16. It is clear that the data models and GIS type and characteristics, as well as the strategies of implementation within the individual institutions will depend on each institution concerned, and will vary from one to the other. Among other factors, they will have to take into account and will be conditioned by: (a) whether it is a source producer, a user, or a combination of the two, (b) the type and nature of the data, (c) the volume and complexity of the data, (d) the analysis required on the data to satisfy the needs of the users, (d) the physical, financial and human resources available, (d) the institutional structures, (e) etc.

17. So far, it would be unrealistic to conceive uniform individual systems within the general national geographic information system network. Each institution will be responsible for

selecting the GIS it will use, but the choice must not be isolated from the rest of the system. What is important is the conditionality that they communicate freely and that the databases are integrated together.

Building up and maintenance of the databases:

18. In a distributed system, with is being adopted more and more widely, the producer (owner) of the data and information is also their custodian. In such context, he defines his own data model and data structure, but will assure that they satisfy the needs of the users within the national information system, and in such a way as to facilitate the up-date and expansion of the content. Data conversion, data maintenance and data up-dating will be the responsibility of the producer. He will also be responsible of making his database fit to the geometry of the fundamental topographic database. In an ideal case, common elements from the two databases would be adjusted to share the same set of primitives, assuring full integrity.

Hence, the conversion of the fundamental database should be done with priority, as the other datasets are just layers to it

19. At any rate, although it implies a greater rate of investment, the conversion of data should be done with great care and within the shortest possible period. The reason of preferring a short conversion period is that the effects and benefits will not be obtained until a complete database exists for at least one application theme covering a comprehensive geographic area.

Organizational and cultural conditions:

20. The introduction of GIS technologies leads to changes not only in existing routines for information exchanges between and within national authorities and agencies, but also entails changes in old-time conceptions on the nature itself of spatial information, conceptions considered immutable in the minds of those who have been producing and managing that information. These changes imply organizational changes within the institutions and also challenges the cultural attitude of the staff, ***at all levels***, as the new technology threatens their system of values. A certain amount of the personnel will oppose to them, either deliberately or not.

21. Institutions switching to GIS must be aware, from the very beginning, that these organizational and cultural problems are more intricate to solve than technical ones, and at the same time are crucial to the degree of success achieved. A great deal of time and attention has to be devoted these matters. Clear and open information on the new methods/goals of the organization to all concerned staff (operational, supervisory and managerial) should be a priority, where an internal convincing marketing of the new working procedures, new products and overall expectations would be earnestly conducted.

Training:

22. Qualified staff is a sinequanom in geomatics. The success or failure of individual GISes will directly depend on the availability of competent staff, who can understand the processes behind the technology. Adequate and continuous training at all levels is required: Operators,

supervisors, GIS applications staff, institution managers and decision-makers.

23. The training scheme will depend on the organization's structure and its resources, on the type and complexity of the data to be converted and used, as well as in the schedule and time-frame for the system's implementation. Some of the staff may be identified within the organization and some will have to be recruited. Some training can be done on-the-job (operators, supervisors) by the system's vendor during the initial installation phase and pilot projects, or, if available, by contracting with some experienced group in the country. If the data conversion phase is done by an external firm, provisions can be made whereby this process is utilized to provide the required on-the-job training to operators. A number of professionals will necessarily have to be sent for formal training and education to universities and specialized training centres, within or outside the country. The Regional Centre for Training in Aerospace Surveys (RECTAS) at Ile-Ife, Nigeria, established under the auspices of the Economic Commission for Africa, constitutes an excellent alternative for training and education in Spatial Information Systems in Africa at the three levels of technician, technologist and postgraduate. It has recently initiated the implementation of a new and full fledged course in Geomatics. The Regional Centre for Services in Surveying, Mapping and Remote Sensing (RCSSMRS), also under the aegide of the commission, although it does not offer regular courses as does RECTAS, organizes short and medium-term training courses in GIS to African nationals. Further, both centres have experience in organizing customized seminars and workshops, which are apt to provide the required know-how for those in (iv) and (v) above.

24. Whatever scheme is applied, any public organization will quickly realize that finding and retaining staff with adequate skills may be a serious problem, as it is the adoption of measures and strategies to solve this problem, such as the introduction of special salary scales and effective incentive strategies.

<u>Database Administrator (DBA)</u>:

25. The person or a group of persons, normally constituted by computer scientist(s) and specialized in GIS design and management, responsible for the overall control of the database. Among other important tasks, he will decide how the data will be defined, stored and structured, he will liaise with partners and users ensuring that the data they require is available and accessed, will define authorization checks and validation procedures, will ensure that the data meets the established standards and that the data and information that is generated flow smoothly both internally and externally. This important and complicated task, which until not long ago was a serious ordeal, has nowadays been eased as most of the major GIS packages of the market have incorporated the necessary utilities of the DBA within the system's DBMS, many of which are performed automatically and efficiently in a way that is invisible to the user.

26. A GIS has been rightfully compared to a car (Konecny, 1993), where the hardware and software supplied by vendors is the car itself, the data is the fuel and the administrator (manager) is the driver, without which the car could not go anywhere (and would serve no purpose).

27. If funds are available, the recruitment of a specialized consultancy firm to perform the

duties of the Database/System Administrator, can be a simple yet satisfactory solution, at least during the entire period of implementation, until the whole system is working successfully and when experts within the organization are highly knowledgeable and familiar with the tasks of the Administrator.

Database design and conversion:

28. **Database design**: During this stage, the content of the database, which is conditioned by the requirements of the users' needs, is defined and documented. A data model, which is an abstraction of the "reality" of a particular application [1], is first developed, representing, in a simplified manner, the entities of interest, the attributes that have to be recorded about those entities, and their relationships. It is then followed by the development of a database dictionary, which classifies, lists and codifies every theme (and sub-themes), object and entity, down to the last identifiable and meaningful element. Examples of a typical data model and data dictionary for a multipurpose cadastre database system are given in annex 1. The database design should include as well descriptions of the specifications and standards, sources of data, and of the processes for data input and conversion, updates, maintenance and archival.

29. At the final stage of the database design, the actual structure of the database is developed and documented against the software platform that, by then, must have necessarily been already selected. However, the original concept of the database should not be confined or restrained to a particular hardware and software, as the lifetime and cost of the database surpasses by far the lifetime and cost of hardware and software. In this regard, data independence is a major objective of database systems.

30. Another important conditionality is that the database design takes into account interfaces and communication with existing and planned computerized datasets, as it is the case within a national geographic information system, more so when the datasets are spread across a network of distributed datasets.

31. **Database conversion**: Several options can be used to populate the database. The process can be done by an external contractor, it can be done internally, or part externally and part internally. Each one possesses advantages and disadvantages depending on the singularities of the organization and the database.

32. There are, however, good reasons that favour the first one, that is external conversion, at least for the bulk of the task:

(i) The database can be very large and therefore, it requires a large number of conversion units (digitizers, scanners, editing stations), all of which are costly and which the organization won't use after the database is completed. *It should be borne in mind that maintaining the database will only need a minimum of units,*

Nevertheless, the database system should be independent from the application. In fact, different applications will need different views of the same data, in particular within the concept of a national distributed geographic information systems, where the different datasets will be use to satisfy the needs of different sectors.

and that data analysis within the organization can nowadays be performed with inexpensive but powerful desktop PC's and software. A large number of experienced operators is also required, who at a later stage may just sit idle, entailing all the problems related to staff redeployment, laying-off, etc. These operators can, of course, be recruited only to perform the task of data conversion, but again they have to be adequately trained, and once the process is over, the institution will lose the investment made. Finally, if the organization can not invest in an appropriate number of conversion units or cannot find and train sufficient operators, then the time to populate the database may increase substantially, postponing results (and benefits), and augmenting the risks of failure.

(ii) The process of data conversion is new to the organization. If not enough care is taken and quality control is deficient, too many errors are bound to be committed affecting the quality of the database, which sooner or later will be detected and will have to be corrected, either via re-digitizing and editing and re-editing, large portions of the database. In addition to unexpected delays, internal and external criticism and pressures, compounded with lack of confidence and frustration, may show very damaging to the implementation of the GIS.

(iii) Data conversion, as other routine tasks, are often carried out more efficiently by the private sector than by the public sector (see below the role of the private sector).

33. At any rate, a close monitoring of the data conversion process must be done, assessing the quality of the quality of results, whereby the data converted is accepted or rejected following a clear set of rules, standards and specifications. The responsibility for such control can be assigned to a unit of the organization, if the required know-how is available in house, or can be entrusted to a specialized external firm.

Pilot projects

34. Pilot projects are essential elements of any GIS implementation plan. These pilot projects are necessary to test that all the components and functionalities of the system meet its objectives.

35. The realization of a pilot project consists of the data conversion of a small geographic area of the data set, which is loaded into the hardware/software selected. Data content and structure, data storage and access, data analysis and queries are verified against the original specifications. The pilot project will also test data conversion and acceptance procedures.

36. Within the context of the national geographic information system, it is clear that an integrated pilot project, comprising data from distinct datasets from different sources, must be designed and conducted, to test, inter alia, data export/import and integration, compatibility among the individual systems of the network, and pilot applications.

Typical components and steps of an institutional GIS implementation process

* INITIATIVE TO INVEST IN A GIS

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* EDUCATION

Orientation to national planners, decision-makers and staff through seminars, workshops, formal and informal meetings.

- understanding GIS
- relational databases, topology, queries
- implications to the agency's role
- performance expectations
- demonstrations

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CONCEPTUAL DESIGN

Establishes the feasibility of GIS, establishes a concept for the system and provides an overall implementation strategy.

- organizational assessment: establishes a starting point: assets and facilities; gaps and deficiencies; staff knowledge and motivation
- * outline of responsibilities and relationships among all institutions involved
- * identification of users' needs and applications
- * identification and analysis of data sources
- * determining datasets, formats, scales and media
- determining training needs at all levels
- feasibility study: estimation of required resources: invest aggressively or within normal budget; cost/benefit analysis
- * study and appraisal by national steering committee

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* APPROVAL

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* SYSTEM AND DATABASE DESIGN

- further development and streamlining of system concept
- data model
- database
- benchmark(s)

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* In cooperation and agreement with the national steering body on geomatics

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* IMPLEMENTATION PLAN

Provides a (normally multi-year) programme of tasks for establishing the GIS

- revision of resources
- strategies for: training
  - selection and design of pilot project(s)
  - procurement and installation of equipment and software
  - data conversion:
  - database and system administration
  - data up-dating
  - data analysis and manipulation
  - overall system appraisal
  - phasing
- schedule of tasks

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IMPLEMENTATION

It is the materialization of the implementation plan

- * training programme launched:
- procurement of equipment: bid/tender documents
  - * analysis of responses, benchmark carried out
  - * selection & award of contract
  - site preparation
  - installation
  - acceptance test
- specific operator's training completed
- data conversion process:
  - external: conversion purchase process
    - pilot conversion: test data base; requirements met
    - full conversion
  - internal: recruitment of GIS data conversion consultant
    - pilot conversion
    - full conversion
- pilot project: test overall system performance
  - * test data transfer and communication within the network
  - * test existent/immediate applications
  - * develop and test new applications
  - test GIS management structure
  - Reassess budget requirements - cost/benefit analysis

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DATABASE ROUTINE MAINTENANCE AND MANAGEMENT

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SYSTEM REVIEW AND EXPANSION

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* In cooperation and agreement with the national steering body on geomatics