INFORMATION INTEROPERABILITY FOR RIVER BASIN MANAGEMENT

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Abstract

Many countries are adopting water policies and legislative instruments for water management in conformance to the agenda 21. According to this agenda, the use and protection of surface water and groundwater are coordinated at a river basin level. The success of river basin management systems relies upon coordinated actions, including provision of and access to information as well as the capability to correctly interpret and use this information. This article presents a discussion on the necessity and benefits of information interoperability for river basin management.

Keywords: Information Systems, GIS, Interoperability, OpenGIS, Decision Support System, DSS, Water Resources Management, River Basin Management, Water Allocation, Water Quality, Water Sectors

1 River Basin Management

Water is a fundamental natural resource influencing human health, ecology and economic development. Flood, water scarcity, desertification, insufficient water supply and sanitation in the poorest population segments, water use conflicts among user sectors or countries, land and water quality degradation arising from population and economical growth, pollution of aquatic ecosystems, erosion and salinization caused by overexploitation and inadequate agricultural practices are water related problems affecting specially developing countries.

Water use has been traditionally managed at a sector level, whereas typical sectors are irrigation, drinking and industry water supply, water delivery, hydropower, fishery, navigation, mining, tourism and recreation. The competition for water between sectors due to population growth and economical development, together with a better understanding of ecological systems, resulted in the development of integrated water management practices. Environmental, economical, legal, social and political motivations has led countries to adopt water policies and legislative instruments for water management in conformance to the agenda 21, in which integrated management practices of use and protection of surface water and groundwater are coordinated at a river basin level. The river basin is a natural, geographical water management unity, permitting a better control over the impact of the water user sectors on water bodies. Due to its interdisciplinary nature, the success of river basin management systems relies upon coordinated actions between water users and other stakeholders of the public and private sector. River basin management involves planning and execution of measures to reduce environmental degradation and to ensure sustainable use of water, including water allocation, water user conflicts, monitoring, protection and rehabilitation of ecosystems.

Many models of river basin management exist, with different participation levels for water users, government and public. Usual organization structures for river basin management consist of one competent authority to enforce legal provisions or of both a river basin agency with executive competence and a committee composed of stakeholders of the public and private sector representing their interests.

The importance of information for water management is exemplified in the EU Water Framework Directive, one of the most significant instruments in the field of river basin management. The success of the Directive relies on close cooperation and coherent action at Community, Member State and local level as well as on information, consultation and involvement of stakeholders, including users. To ensure their participation in the establishment and updating of river basin management plans, it is necessary to provide proper information of planned measures and to report on progress with their implementation with a view to the involvement of the general public before final decisions on the necessary measures are adopted. The information should be as far as possible available for introduction into a geographic information system (EUWFD, 2000).

Water related planning and operation activities in the river basin require the access to data from external sources. Construction, operation and maintenance of pipelines, water mains, wastewater canalization, electricity cables, gas distribution and roads, in the public or private sectors may affect one another, requiring usually official authorization and coordination by the governmental administration. The authorization process requires a spatial analysis - in the simplest cases through visual inspection - to determine the influence of a planned activity on other sectors operating in the area of concern.

River basin agencies construction, operation and maintenance obligations, like abstraction and impoundment control, control of direct discharge into water bodies, taxation, prevention of flood and accidental pollution, surveillance and monitoring of water quality require a system capable to access and manage information from innumerous sources. Access and provision of information between stakeholders depend on technological and organizational factors, like the capability to interpret the data (semantic interpretation), data quality, scale and time dependence of key processes, network and computer infrastructure and agreement on data use. One of the most significant challenges of integrated water resource management is the information integration.

2 River Basin Information System

The information technology has experienced enormous progress during the last years, being widely applied in the field of water management. The advances in this area bridged the gap between computational scientists and water specialists, permitting the development of more efficient information systems. The object oriented technology and the quasi-standard unified modeling language (UML) enhanced the communication between water and computer experts during the model analysis and design processes, leading to more reliable, extensible and interoperable models and products.

A river basin information system relies upon diverse fields of the information technology like database management systems, geographical information systems, numerical simulation, geostatistics, expert systems, neural networks and decision support systems. A river basin information system supports decision makers and water experts in the planning, operation, evaluation, monitoring and reporting tasks of the river basin management system. Planning tasks requires hydrological, environmental, and socio-economical data, data on water abstraction, release and quality, land use and infrastructure.

Geographical Information Systems (GIS) and database management systems are part of a river basin information system. GIS supports the collection, storage, analysis and presentation of spatial and non- spatial data. It allows multidisciplinary spatial analysis, including socio-economical, ecological and hydrological analysis. Extended data models provide integration of geospatial and temporal data describing surface water hydrology and water infrastructure management. Diverse GIS products are integrated to commercial database management systems.

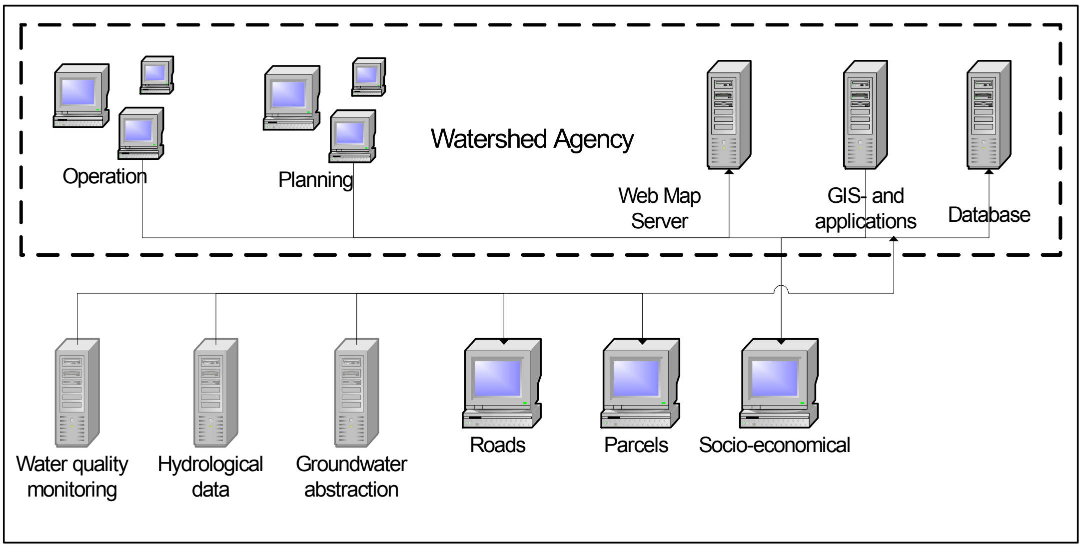

Fig. 1: Schematic representation of interoperable water information systems

A further feature of a river basin information systems is the integration of GIS and computer simulation models to solve water specific problems. These include water allocation, groundwater flow and transport, runoff, erosion, reservoir operation, water quality, irrigation and drainage. The single-objective, single-purpose, and single-facility project approach to solve water resources allocation problems that was common in many water planning agencies in the developed countries in the past has gradually been replaced by multi-objective, multipurpose, and multi-facility solutions at the river basin level (McKinney, 1999). The data retrieve for water models and its integration with GIS required for planning (including resource allocation), operation and maintenance may be implemented from lose coupling of ascii files through import and export methods, to tight coupling of databases through the definition of an appropriate data model, to distributed computed platforms like J2EE, COM or CORBA. The results of a simulation model are used as parameter for another model in an integrated environment. The data necessary for simulation –material properties, boundary conditions, initial conditions and constraints are better defined in a geographical information system, based on the properties of the concerned area, then in the numerical models as properties of finite elements or finite volumes. In an integrated modelling environment the user is primary concerned with the description of a physical problem and not with the preparation of a numerical simulation, making modelling more natural, appealing and reliable. Adaptive methods for finite elements, i.e. the optimization of the finite element meshes, retrieve their parameters from the GIS-model in which its embedded (Roehrig, 1998). The attribute enhancement in a GIS model using inverse methods, i.e. an optimization problem to determine material properties starting from numerical solutions, show that data transfer between GIS and numerical simulation is a two-way process.

Decision Support Systems (DSS) are responsible for interoperability, embedding simulation models and GIS to analyse different measures through scenario development. DSS are used in river basin management to predict ecological consequences of water activities and land use changes, as well as an instrument for the development of environmental goals for different ecosystems (Kofalk et al, 2001). Database, interface, and model connection illustrate the major advantages of using a GIS and decision support systems (spatial decision support systems) for river basin management (McKinney, 1999).

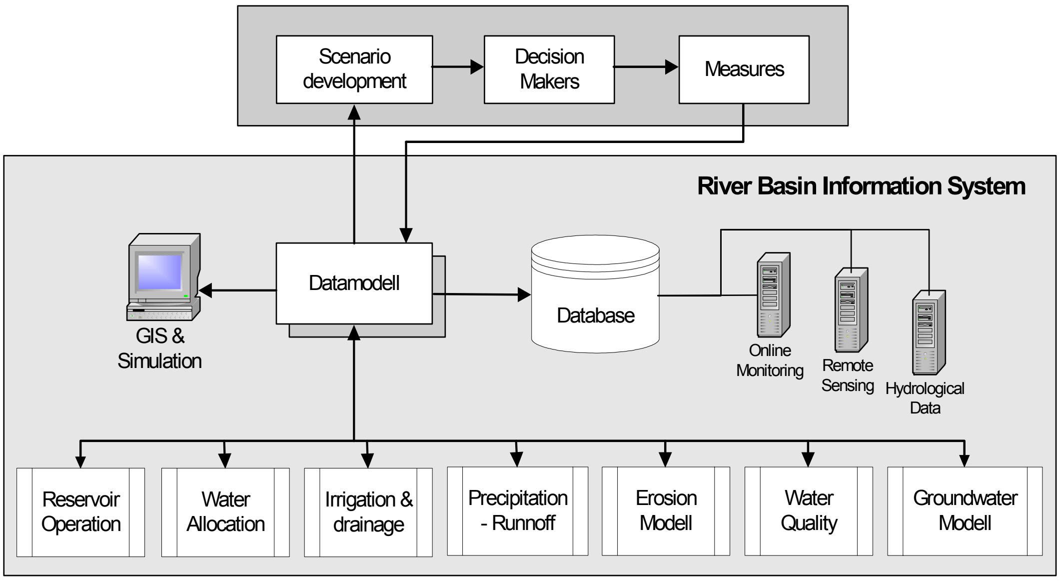

Fig. 2: Schematic representation of model interfaces

3 Interoperability

Information systems require considerable investments to create and maintain spatio-temporal data. Sharing data between users from different institutions helps to return the investments for data providers and to sink the costs for data consumers. Joint projects to share data costs help to improve the data quality and avoid data redundancy. Integration of data and services makes GIS more attractive and facilitates its understanding and usage.

The different proprietary formats of GIS products makes the investment sharing for data acquisition and maintenance difficult. The widely used import and export functions are errorprone and cumbersome due to a small automation grade. Information losses caused by data conversion can occur through geometrical approximations or omission of part of the original data, like topological information or metadata description. Specially the exclusion of metadata compromises the data quality control.

Interoperability enhancement is a response to the benefits of data sharing. It is the capacity to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units (ISO 2382-1). Geographical interoperability is the ability of information systems to a) freely exchange all kinds of spatial information about the earth and about the objects and phenomena on, above, and below its surface, and b) cooperatively run software capable of manipulating information over networks (OGC, 2002).

Diverse initiatives are being conduced to provide geospatial infrastructures, permitting the access and integration of data, like the Open GIS Consortium (OGIS) and the International Organization for Standardization's Technical Committee on Geographic Information/ Geomatics (ISO TC/211). The objective of OGC is the full integration of geospatial data and geoprocessing resources into mainstream computing and the widespread use of interoperable, commercial geoprocessing software throughout the information infrastructure (Buehler and McKee, 1996). An example of geospatial infrastructure on regional level is the GDI (Geospatial Data Infrastructure North Rhine-Westphalia), created in 2000 with the goal of developing the market for geographic information in the German federal state of North Rhine-Westphalia. This will be achieved by connecting the value chains of users, service providers, service enablers, integrators, data producers, and infrastructure providers (Brox, 2000). The operative coordination of GDI is accomplished by CeGI - Center for Geoinformation GmbH (CeGI, 2002), an initiative supported by the German federal state of North Rhine-Westphalia to coordinate actions between the public and private sector, acting as a competence centre to improve the geospatial infrastructures in North Rhine-Westphalia.

The Open GIS Consortium specification *OpenGIS Service Architecture* and the ISO/DIS 19119 provide a framework to develop interoperable systems to access and process geographical information (OGIS, 2002). In this context the service is that functionalities are provided by interfaces. The fundament of this specification is the standardization of interfaces according to the undergoing approaches in the field of information technology, like the *Reference Model of Open Distributed Processing* (ISO/IEC 10746). The Open Distributed Processing is based on message oriented services, service chaining and service metadata (computational viewpoint), mechanisms for distribution, distribution transparencies, supporting services such as security and persistence (engineering viewpoint) and infrastructure that allows the components of a distributed system to interoperate (technology viewpoint).

Interorganizational aspects of data and service sharing have received less attention than technological issues, although considering only technological problems is unlike to permit a successful data and service sharing. The interorganizational context refers to the organizational factors and interdependencies that influence coordination and decisions about joint GIS and database activities (Nedovic-Bodic and Pinto, 1999). Interorganizational systems and databases are manifestations of the interorganizational relationships (Kumar and Dissel, 1996) and model of government (Westin, 1991).

There are many institutional barriers to overcome in order to dispose of the benefits of data and services sharing (Nedovic-Budic and Pinto, 1999; Campbell and Masser, 1995; Citera et al, 1995, Al-Romaithi, 1994). These barriers include a) political acceptance and legal agreement to exploit public data commercially or not, including accessibility of public data by public institutions or the private sector; b) ideological barriers, vertical governmental structures; c) dependence on external data, loss of monopoly, autonomy and control over information; d) different interests and priorities between data providers and users, including access reliability, data quality, level of awareness and spatial data handling skills. Developing countries are in many cases consolidating economies and democracies, where sectors like water are considerably dominated by nepotism and political influence, creating difficulties to the implementation of information access programs. The motivation to share data reflects not only infrastructural and technological advances, but also more transparent and participatory government information politics. Transparency and involvement are also important requirements for river basin management.

Interoperability standards lack specifications related to interorganizational aspects. Interorganizational aspects are concerned with the purpose, scope and policies of an enterprise or business and how they relate to the specified system or service. The interorganizational context has a strong influence on the sharing practices and interoperability requirements. Financial and organizational efforts necessary to the improvement of interoperability can pose insurmountable obstacles, specially for developing countries. Technical problems leading to a limited interoperability include network bandwidth, computing infrastructure, reliable power supply and expertise. The investments necessary to overcome these limitations and to implement river basin information systems based on interoperable information systems may be prohibitive when compared to the budget designated to accomplish the basic measures provided for the river basin management plan.

The interorganizational context of river basin management is usually formalized through law regulations and legitimated through stakeholder participation, contributing to reduce resistances against data sharing and facilitating the establishment of interoperability policies. Solving interorganizational problems of the information interoperability between stakeholders may contribute significantly to consolidate the operation of the river basin agency and to implement the measures provided for river management plans. Information interoperability provides the fundament to coordinate the actions between agency, water users, government and public. This applies specially to new river basin agencies in developing countries. The inherent interorganizational difficulties encountered during the formation of an agency are comparable to those encountered in the development of interoperable river basin information systems, as for example insufficient staff and technical resources, institutional disincentives, historical and ideological barriers, power disparities, differing risk perception (Citera et al, 1995), staff turnover (Sperling, 1995), different priorities between participants, agreement over access to information and leadership (Campbell and Masser, 1995).

Few comprehensive efforts have been attempted to implement geographical interoperability standards for river basin information systems. One successful example of interoperability is the pilot project of the city council of Wuppertal (Germany) and the river basin agency Wupperverband, one of the 11 river basin agencies in North Rhine-Westphalia created at the beginning of the 20th century. The land survey office of the city council provide e.g. parcel data to the river basin association for planning and operation purposes. Wupperverband provides water related GIS-data to the city council for approval requirements also involving other sectors (Sander, 2002). Both institutions use different GIS platforms, and the data sharing technology is based on the OGC standard *Web Map Server (*OGIS, 2000).

4 Conclusions

Information interoperability is part of the river basin interoperability in a broader sense. Overcoming the difficulties to implement information interoperability is a fundamental step forward to consolidate a river basin management system. This involves analysis of information flow, access agreements and restrictions, access directions (one direction or both), data access rights and data provision obligations. The discussion on data transfer offers an opportunity to (re)evaluate the business process of the participants of an integrated river basin management system and to improve underlying data models. Defining information interoperability enhances the stakeholders involvement and formalizes management actions, reducing the complexity of the implementation of the river basin management system.

The scope of the OGIS service architecture can be extended beyond GIS interoperability and comprise other components of a river basin information system in a framework for open distributed processing. Simulation and optimization models are in this context service provisions or combinations of services through service chaining. Interoperability specifications like *OpenGIS Service Architecture, OpenGIS Feature Geometry* (OGIS, 2001), *OpenGIS Web Map Server Interface* (OGIS, 2000) and *OpenGIS Features* (OGIS, 1999) can provide a framework to develop interoperable decision support systems for river basin management.

GIS-interoperability can contribute significantly to implement a river basin management system, helping to overcome institutional barriers and enhancing the legitimating of water agencies through stakeholder involvement.

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