Development of National Spatial Decision Support Framework for Sustainable Development

Rania Elsayed Ibrahim, Amr Elramly
National Authority for Remote Sensing and Space Sciences, Cairo, Egypt.
raniaelsayed@narss.sci.eg, amrelramly@hotmail.com

Abstract

Background: The decision-making process in an organization succeeds when it is comprehensive, reliable, and done in a transparent manner between the departmental management as well as the stakeholders. It also requires complete and correct data to feed the decision process tools and applications.

Methods: We designed a socioeconomic approach to build the National Spatial Decision Support System and provide support for the national economy development. The approach is proposing web based platforms for collaboration between government authorities, industry experts and the public. The collaboration is implemented by building one platform for the experts called the Experts' Collaboration Portal and another platform for the public called the Geospatial Businesses Portal (GBP). Both portals are considered as an envelope on top of the e-government services and are the sources of big data from the public and the industry, which represent all areas of the national economy and the public assets.

Results: National Collaboration for Sustainable Development Spatial Decision Support Portal (NCSD-SDSP) is designed based on previous practices in NARSSGeoPortal to support the national spatial data sharing between the government authorities for the natural and human resources and all other areas of the Egyptian economy. The system provides tools that accommodate "big data" and verify the completeness and correctness of the spatial data. The system also facilitates the data sharing and consolidation, spatial analysis and modeling, and the decision support tools. While NCSD-SDSP is designed to capture all required standard policies and regulations for the data sharing, it is also the tool for policy automation, and metadata handling.

Conclusion: This paper proposes a national collaboration framework based on socioeconomic approach to build the national geospatial data infrastructures and facilitate public information channels that provides sustainable, complete, and correct national resources data (big data) flow required to support the stakeholders' decision-making and the national sustainable development management.

Keywords: *knowledge-based system; National Spatial Decision Support framework; socioeconomic approach; Sustainable development; National Collaboration.*

1. Introduction

The decision-making process in an organization or business should be planned and resolved in a comprehensive, reliable, and transparent manner. Managers will not be able to make their organizations more efficient effectively without access to adequate information, analysis tools, and monitoring systems. Quality and well-timed decision-making is fundamental in the success of any organization. It requires successful implementation of decision support tools to adequately inform the decision process [1].

The decision-making process in an organization should be planned and resolved in a comprehensive, reliable and transparent manner between the departmental channel management as well as the stakeholders. It requires successful implementation of decision support tools to adequately inform the decision process.

National Authority for Remote Sensing and Space Science (NARSS) is a spatial GIS service provider to the stakeholders in ministries, the Cabinet, and the provinces that is required to provide the latest technology tools to help in land use planning and selection in addition to other spatial applications. NARSS setup a program to promote a sustainable development support agenda nationwide based on partnerships with national institutions, provincial partners, and key GIS partners. The partnership initiative designed to extend the functional capabilities of national institutions by developing mutually supportive relationships. At the initial stage, these relationships focused on training and dissemination of GIS. Ultimately, NARSS program seeks to develop a robust, productive GIS environment to attain complete and accurate information required to support the national sustainable country development.

Although NARSS is doing their best in providing such service, global maturity level of handling data and information may not even reach 10% of the required data value and the purpose of usage. That is due to the unnecessary redundancy in processing the same inquiries from different parties and stakeholders.

In our previous work (2014-2016) in NARSS, we developed a spatial data sharing portal under the name of NARSSGeoPortal (http://geoportal.narss.sci.eg/opengeoportal) that meets the government authorities' needs in consolidating all national spatial layers and maps created by the authorities. The efforts were communicated to the authorities who in return appreciated the effort and decided to formulate a special high level committee from government authorities to contribute in a full National Collaboration for Sustainable Development Spatial Decision Support Portal (NCSD-SDSP).

NCSD-SDSP support the exchange of information of the spatial distribution of the natural and human resources, industrial, agricultural, tourism, and all other areas of economy. It provides monitoring for land use to detect the encroachments on the land. It monitors the causes of hazards, disasters, and pollution in near real time. The system will accommodate large amount of complete and correct spatial data or in other words "Big Data" and provide classification, analysis, modeling, and audit.

The proposed system is a knowledge-based decision support system [2, 3, 4] and provides platform to facilitate building management, planning, and monitoring tools. It contains structured human resources to provide the knowledge and to feed the system with the public "big data". The system also includes hardware, network, software, data, data entry, database, and the policies governing data exchange.

Dealing effectively with big data [5, 6] nationwide must require collaboration and integration between government and public citizens in one powerful web-based information

system [7]. Integration with public can be implemented as web-based governmental services [8]. This way, the public user of the service will be required to provide information related to the service, as well as the user's profile. This information will lead to numerous ways to assure correctness and completeness of the collected data [9]. The proposed system is based on the mobilization [10] of the citizens' geospatial business information within the system where the public get engaged personally or through their businesses.

The system presents new challenges in concept and technology not only for the established areas of data and knowledge engineering but also for the evolving efforts on metadata management and information modeling: (i) new methods integrating data and knowledge throughout the information management lifecycle (from modeling to representation and processing), (ii) new methodology unifying enterprise metadata management with information modeling, and (iii) new technology and architecture to simplify the complexity of information control.

The overall design philosophy of the project follows three major principles: a) adhere to the national data sharing policy and standard to ensure interoperability, b) use free and open source software components whenever possible c) build and record knowledge as we go, while transferring that knowledge through the system built-in help, support, and training tools.

The remainder of the paper is structured as follows. Section 2 gives related literature review in brief. Section 3 explains the methodology and solution approach. Section 4 shows how this paper contributes to theory. Section 5 discusses the results. Finally, section 6 gives a conclusion and further work.

2. Related Literature in brief

There is a lot of literature on e-government portals and knowledge management, with topics such as the use of GIS-based support of recreational trail planning by local governments [11], a web-based information system for planning support [12], electronic government as a paradigm shift for efficient public services for Nigerian government [13], and a strategic operations management framework for service delivery [14]. In a case study in Australia, [15] studied e-government services in the local government context. Barriers to e-government integration were also studied by [16], while Enterprise integration in e-government was studied by [17]. Challenges and opportunities of e-government in Jordan were explained by [18].

A new approach to a local e-government portal for information management and deep searching based on semantic web and ontology was proposed by [19]. A new framework to supply citizens with adapted content and personalized services that satisfy their requirements and fit with their profiles in order to guarantee universal access to governmental services was proposed by [20]; the proposed reactive and proactive solutions combine several recommendation techniques that use different data sources i.e., citizen profile, social media databases, citizen's feedback databases and service databases. The South African Spatial Data Infrastructure (SASDI) was initiated [21] that discussed the main components that comprise the SASDI. The study [22] developed a geographic information system framework for transportation data sharing that built a schema for transportation features and their identifiers and provided a basis for the development of the framework and principles for sharing transportation data. The study [23] assessed the importance of e-government services and website success factors from the perspective of citizens using multi-group analysis in Thailand and Indonesia, they found citizens in both countries interpreted the survey instrument similarly but had very different expectations for their e-government services.

There are also some studies implemented decision support systems in specific areas such as air pollution management, agriculture, mining and irrigation as in [24, 25, 26, 27]. Decision support systems were also implemented for emergencies and clinical data [28, 29].

3. Methodology

3.1 Data

Empirical data has been collected during the project of NARSSGeoPortal aimed at developing a spatial data sharing portal that meets the government authorities' needs in this regard. The research process was inherently intermix with the design, building and evaluation of the platform that was developed within a collaborative and organizational context. Multiple research instruments were employed in order to collect data that was necessary for delivering project results such as memos, progress reports, and prototypes. Throughout the project, a series of interviews were conducted. Respondents included project members, IT architects, business managers and policy makers. The interviews were semi-structured around questions concerning the planning issues and design of the platform. The development of the project was from June 2014 to June 2016 focusing on (1) the development of a national information sharing system for data exchange through collaborative platform, with emphasis on the interface definitions, data standards, and semantics. (2) The development of data exchange policies based on the information exchanged via the platform. The fact that the authors were also involved in the research and design in the projects means that we had full access to all details.

This paper takes this project as case study methodology [30], our aim is to propose solutions for the next phase of NSDSP based on previous practices in building a NARSSGeoPortal.

3.2 Planning Issues

Hereinafter, some issues are raised when planning to build a consolidated Spatial Knowledge-Based Decision Support System to serve the Cabinet and the stakeholders.

First issue: NARSS did not have enough integrity with the stakeholders or the Cabinet data services. That sometimes led stakeholders to build their own tools and resources to get the information they need instead of collaborating with NARSS services. Consequently, segregated knowledge is created and it became impractical to provide complete information accurately and in time.

Second issue: Spatial data will be more readable and valuable if it is ruled by some guidelines from the stakeholders and the Cabinet when requesting GIS and spatial information. Also, constrains should be taken into consideration if there is a conflict between authorities or overlapping in resources because no stakeholder claims ownership. We may see that Cabinet and some dedicated authorities are taking care of this issue but not integrated technology wise. Also the assurance of having all concerned parties involved may not be valid.

Third issue: there is a lack of knowledge of the common standards that should be used and how to impose it on a system. It is similar to challenges in finding the proper way to implement the policies within the workflow of the data sharing system. In both cases (policies and standards) we need to create methods and build tools to handle the metadata in a standard way and to transform the policies context into process.

Forth issue: there is no enough data or information to feed the system. We believe that the amount of data and information required should be thousands times of the available ones.

Also the correctness level of the collected data must be elevated. The amount of information required will need enormous human resources to collect and make it available to the system.

Fifth issue: we live in an era of dynamic ecosystems with a high rate of transformation. Traditional way of building information system for static organization structure is not sufficient anymore. What is really required is to build a knowledge-based information system that is dynamic enough to cope with our dynamic ecosystem.

3.3 Proposed System

NCSD-SDSP is designed to support exchange of information on the spatial distribution of natural and human resources, industrial, agriculture, tourism [31, 32, 33] and all other areas of the Egyptian economy. It provides monitoring for land use to detect the encroachments on the land. It monitors the causes of hazards, disasters, and pollution in near real time. The system can accommodate large amount of complete and correct spatial data or in other words "Big Data" and provide classification, analysis, modeling, and audit.

The NCSD-SDSP (Fig.1) is designed to reside on top of the National Spatial Data Infrastructure (NSDI) [34] and to provide tools for data sharing and consolidation, image processing, spatial analysis and modeling, monitoring, warning and alerting, and finally stakeholders' decision support for national development operations. NCSD-SDSP also provides the standards and policies automation, and metadata tools. A web-based GIS experts' consortium portal and a geospatial public services' portal are two more applications proposed for collaboration with experts and public society.

Our approach is to use open source software systems that are well proofed and recognized [35, 36] and which we used before to build NARSS data sharing portal. In the second phase, we moved to perform image processing, spatial data analysis, and modeling. The open source software required will be QGIS and GRASS from OSGeo while PHP framework will be used to develop integration, API/REST services, access control, metadata tools, bulk upload, and more web pages and forms.

In basic operation, satellite images is loaded to QGIS and get prepared to run internally on the integrated GRASS for analysis and modeling then integration server(PHP) passes the outcome to the decision support system GUI(PHP) for viewing. Then, finally is the stakeholder Control and Command module (PHP) where the stakeholder may examine trends of "what if" which performed by the query server (PHP) or send decision to assigned authorities (PHP) or automatically send alert and warnings in case of disaster and emergency (PHP).

This system is a knowledge-based and provides platform to facilitate management, planning, and monitoring tools. It contains human resources to provide the knowledge. The system also includes hardware, network, software, data, data entry, database, and the policies governing data exchange.

NCSD-SDSP is a system that includes the software, GIS experts, and socio-economy platform. As such, it is considered a method for integrating applications with people and experts to provide sustainable evolution to a system that continuously upgrades itself to the required maturity level and stays "state-of-the-art" all the time.

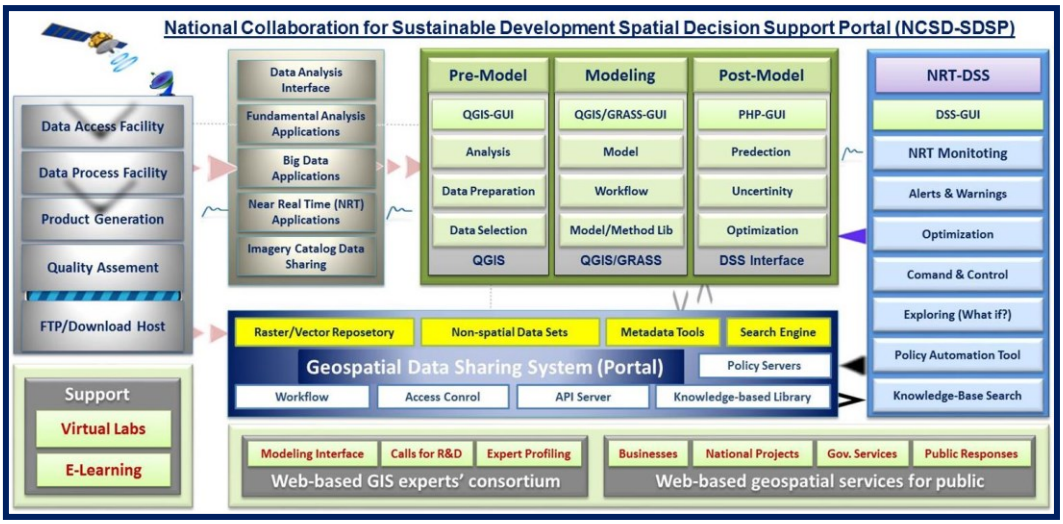

Fig. 1. NSDSP Architecture

Multi-sources of information will not be sufficient unless gathered in "big data" manner [37] that will be available if we get the public engaged in feeding the system with information. The big data requires smart system [38] for searching and for comprehending, like the knowledge-based decision support system. Also, a focused and condensed training must be conducted for all parties engaged.

The NCSD-SSDP is not only a web-based system [39] but also a methodology for human integration [40] within the system. The project introduces a method for data collection, data management, and data quality control. Each of the subsystems for NCSD-SSDP has additional benefits as follows:

- ***Geospatial Data Sharing System (Portal)*:** To facilitate searching, viewing and exchanging geospatial data and information which was implemented under the name of ***NARSSGeoPortal***.
- ***NRT-DSS Portal*:** It is a Near Real-Time Decision Support System to facilitate monitoring and reporting Geospatial status for areas of interest in near real time and to enable stakeholders to ***explore "What if?"*** scenarios to predict future results for each planned action and the consequences of particular decision if taken. The portal also facilitates ***Command & Control*** to convey the decision made downward to the appropriate authorities to take the necessary actions.
- ***Standards and Policy Automation System*:** To facilitate feeding the standards and policies, and imposing them on data sharing and modeling within the system.
- ***GIS Experts Collaboration Portal*:** To engage the GIS experts for contribution and to provide tools to create models, perform analysis, conduct studies, and propose solutions. The portal will facilitate automatic and manual feed of calls for solutions, studies, modeling, and analysis.

  It is a website and association to assemble experts and specialists in geospatial information technology from national entities, individuals, bodies, companies, universities, and stakeholders. The purpose is to enrich the knowledge and the exchange of experiences toward better information systems. The association will receive the

problems that need a study or a solution, then, request participation in finding solutions and practices. The association will provide a good environment to develop open-source software to support decision-making and problem-solving at hand. The web-based service will present studies, call for participation in a project, and call for modeling similar to the services provided by Freelancer website. Also the participant, after approval, will get connected to the project and the resources from data and tools, so that the expert can provide assistance, develop model, create analysis method, and/or conduct study.

- ***Geospatial Businesses Portal (GBP):*** Described as virtual socio-economy platform, where it is implemented as web-based applications that generate micro business units. As seen in the Fig. 1, it collaborates and integrates Businesses, National Projects, Government Services, and Public Responses. GBP creates self–financed, self-managed, and self-quality controlled sustainable developed businesses, while providing accurate and validated information required for the NCSD-SSDP system. The portal generates millions of business opportunities in multiple disciplines and billions of dollars in revenue. The GBP is an envelope for the e-government services and extend the reach to the public citizens.
- Geospatial business applications are web-based services provided to the public in multi-disciplines like farming, manufacturing, food supply, transportation …etc. It is designed so that the citizens will subscribe to the services and build their own profiles. It also provides services for their properties and businesses which will be the sources of information about the national assets and private resources. Finally, it will also provide a way for public to report on hazards. Public input is one of the best validation methods. The system should be open to public through web-based applications to gather as much real verified data as possible. No other system can be challenged against millions of public subscribers feeding information about their properties, farms, crops, businesses, what they see, what they found, pollution, leaks, bird disease, sand storm, rare species …etc. Other examples of alerts like utility shutdown, road congestions, and repairs. The intent is to encourage businesses and public users to feed the system with data meaningful to stakeholders to gain accuracy, details, and more metadata. For example, the actual vegetation reported by farms' owners will add a way of improving accuracy that could be used in crop recognition from space. Reported construction on agriculture land may help in building violation alert-based system. There is a long list of the public interest to report and will be willing to report if the public can find easy way to report. Note that these types of data are huge and free. It is also the type of data required for Decision Support System and cannot be gathered by hired staff.
- ***Report Manager*** is a normal reporting system and can be configured to generate reports, email status, and alert certain authorized bodies in case of emergency.
- ***DSS Panel*** is the decision support panel with customization tool to facilitate customizing the panel to the stakeholder preferred view. The DSS will be used by all levels from the small governmental office in a small village to the regional and provincial offices up to the mayor, minister and Cabinet offices. It is planned to facilitate multiple screens' view for control rooms and monitoring rooms.

- ***The DSS system*** will provide the stakeholder with workflow to expedite their decision and convey orders to the assigned bodies. The workflow may also be set to work automatically for any threshold value triggering high alerts for fast action and response like in case of disasters or emergencies.
- ***Knowledge-based Library System:*** The wiki-search is designed to store data analysis methods and data models with related metadata that appears on the Wiki-search GUI. This is handy for the stakeholder to try and build "what if?" scenarios. What if? Is a trend explorer tool for the stakeholder to perform exercise by changing the attributes' values and examine what if a parameter changed from a value to another? The tool provides many options and provides on spot behavior change. It is planned to provide the stakeholders with all information they might need to know about their area of interest.
- ***API/REST server*** is used to provide simple interaction and messaging between sub-systems. It is the core system to do integration between sub-systems and act as Query Server, Relay/Proxy, Messaging Server, Access Control Interface, and Data Exchange.

3.4 Scenario of operation

The system is based on using satellite and airborne imagery plus pre-produced maps and spatial layers [41]. Images that will be continuously received on a timely manner [42, 43] will automatically be placed into data analysis and modeling sub-systems already programed with adequate modeling design [8,44]; the modeling systems will produce the outcome of the models that are also being pre-programed. One of the most used methods in analysis is the "change detection," particularly, in monitoring. Multiple analysis scenarios may apply to provide interpretation for the change detected and provide means of values or alerts. Then it uses modeling workflow in conjunction with integration modules to automate presenting the outcome from the modeling systems to the decision support screens where the decision maker can monitor or get alerted.

The open source software packages; QGIS, GRASS, and R (language) as a combination are used for producing data layers, data analysis, data modeling, statistical analysis, and image processing and to also satisfy the scenarios explained above. PHP framework is used as an integrator and access control between subsystems and for the Decision Support GUI interface.

QGIS/GRASS/R will be used to create spatial layers, image processing, data analysis, and data modeling. The good news is that QGIS, GRASS, and R (language) are fully integrated suite. In basic operation, satellite images are loaded to QGIS and are prepared to run internally on the integrated GRASS for analysis and modeling then integration server (written in PHP) passes the outcome to the decision support system GUI for viewing. The control and command module helps the stakeholder to examine the trends of "what if" which is performed by the query server (written in PHP). The stakeholder may also send decisions to assigned authorities or send alert and warnings in case of disaster and emergency.

3.5 Optimistic Issues & Factors

In the previous scenario, some monitoring models may work accurately if the only input data required are satellite images and if the change detection recognition is well calibrated and scaled. Hereinafter, there are four main issues that should be studied and considered.

First issue is that many cases are a natural phenomena that change behavior over time and space. Some of these cases need to be compared with other ground sources of data for

calibration and suitability. Ground sources may also evolve/change over time and require continuous update.

Issue 1: Continuous updated sources of ground data are required for calibration and suitability.

Second issue is that in analysis and modeling of nature or ecosystem, we follow the best practices. Over time, better modeling and analysis practices/methods may be introduced.

Issue 2: Analysis and modeling tools should be open, to review the methods used in the tools and validate the correctness and suitability of the results.

Third issue about environment around the area of interest may also change and might cause wrong results if not periodically remodeled.

Issue 3: Environment periodical review is required.

Fourth issue is the change in equipment and technology used for testing and cameras used for imagery will change the calibrated scales. Analysis methods and modeling may require change or modification.

Issue 4: New remote sensing data sources must be reviewed or remodeled.

There are definitely many other issues that might be unknown and outside the scope of this paper to discuss. We also propose to add two factors to consider in building better and more accurate modeling for better results.

The first factor is to bring more experts very close to the cases under analysis and provide them with tools to contribute in improving continuously the analysis methods as well as to enhance the models. That is proposed as a *web-based expert consortium subsystem*.

The second factor is to add sources of information as much as we can. We propose a subsystem as a *web-based geospatial services and businesses for public.* Where the public is engaged in all areas of interest and provide real valuable and accurate sources of information that can be used in modeling and analysis methods.

4. Contribution to Theory

This paper presents a framework which consists of an integrated architecture for business process management. The emphasis is on the use of knowledge bases in the different stages of process design, interface modeling and execution. Furthermore, the architecture supports process instance execution using simple web interfaces. For this reason, all the domain information is organized into appropriate knowledge bases, depending on the corresponding fields (i.e. related to regulations, enterprise, business processes, etc).

5. Results and Discussions

This paper developed a framework to geospatial information system to consolidate data, build unified infrastructure, and collaborate technology users by proposing a full collaborated national spatial decision support system and the required data infrastructure. In this regard, the project purpose is to sustain enterprises during knowledge management activities by: (a) Unifying the knowledge of everyone in organizations. (b) All parties are agreed on using unified standards that will contribute to the international geodetic reference. (c) Unified agreed platform for data sharing between all concerned parties. (d) All parties are transferred from segregated paths of knowledge to collaborated path to provide all information required, accurately and in time to fulfill the requirements for each concerned party. (e) Improve

economy by defining standards, policies, and regulations. (f) History of all events and inquires with the supported policies will help reuse in similar cases plus conflict resolution and interrogation will be supported by history document. (g) Cabinet and stakeholder will focus more on building more policies that brings more opportunities as well as protecting their ownership. (h) Reduces the overall costs of operation drastically for NARSS, stakeholders and the Cabinet when moving from providing raw data to business intelligence information.

There are two factors to consider in collaboration. The first factor is to bring more experts very close to the cases under analysis and provide them with tools to contribute in improving the information system. That is proposed as a web-based expert consortium subsystem. The second factor is to add sources of information as much as we can. This paper proposed a subsystem as a web-based geospatial services and businesses for public. The intent is to encourage businesses and public users to feed the system with data meaningful to stakeholders.

The proposed approach reflects a quantitative method for capturing network-based inter-communication between actors involved in a certain event through Web based services methods such as REST/API, SOAP. It also includes the view that infrastructure should be seen as a process, since it is created by a large number of factors.

The proposed system can facilitate managers to enhance their capacity for analysis and management by generating real-time information networks. It also allows researchers to collect real-time data, information and datasets that might be useful in scientific research i.e. conduct real-time analytics by developing forecasting and prediction models. Both researchers and participants with the proposed approach have an innovative data driven method to efficiently collect, process, and analyze web-based data for identifying the needs of local communities. However, collaboration between governmental agencies and citizens may become critical in providing time-critical public information services.

6. Conclusion and Further Work

This paper shows how to build a full collaborated national spatial decision support system and the required data infrastructure. It provided full solutions that appear to be useful to any government that intends to use an open data program to help pursue its policy goals.

Further work, the proposed system need to be tested in additional cases to further verify its validity and usefulness in diverse cultural and political settings. New cases might identify additional components or detailed factors within components that are universally important for designers to consider.

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