GIS FROM THE GROUND UP: DEVELOPMENT AND IMPLEMENTATION OF A GIS FOR RAS AL KHAIMAH – UNITED ARAB EMIRATES

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ABSTRACT

Ras al Khaimah (RAK) Emirate has historically kept hard copy records of its geospatial data. In recent years, the Emirate used AutoCAD mapping. This standalone system, as a whole, did not support additional staff responsibilities resulting from transactions and record growth as issuing sit plan and building permit applications increased approximately 60 percent over the past year. RAK was beginning to discover the potential value of Geographical Information Systems (GIS) as a total data management system that fosters an efficient decision-making process. The Emirate establishes enterprise GIS project, parcel mapping and other spatial data have been migrated from AutoCAD to ArcGIS, thus providing greater access to other GIS information. Maps and data will be available to the public through ArcIMS. This paper will look at how RAK has been able to justify and implement an enterprise wide spatial database and high GIS technologies. The paper will also demonstrate how Ras al Khaimah GIS project (RAKGIS) infrastructure was constructed by analyzing the implementation of RAKGIS project and its benefit to the Emirate.

Key Words: Implementation, GIS, Enterprise, Ras al Khaimah, UAE.

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INTRODUCTION

Ras al Khaimah (RAK) Emirate is changing. It is the fourth largest of the seven emirates that form the United Arab Emirates (UAE) located on the Arabian Gulf, between Latitudes 25 and 26 degrees North and Longitudes 55 and 60 Degrees East extending over about 3000 Sq Kms (Figure 1). The Emirate is growing both in population and service needs. It is fast becoming a place to live for many new residents who work in and commute to close Emirates. These new residents are bringing with them more expectations of government services and as with any government, the government staff members are expected to do more at the same or less cost than they have previously done in the past. Along with this growth are strains on management of infrastructure and an increase in information requests.

The use of a Geographical Information Systems (GIS) can help to abate some of these problems, but knowing how to go about implementing GIS successfully has been a challenge for some municipalities (Waite, 2005). RAK officials also recognize the opportunities that exist when considering the implementation of GIS both in terms of a data storage/access system and also as a means to update and streamline their existing work flow business processes. GIS can provide the means to track data, prioritize maintenance and streamline customer requests (Longley *et al*, 2001). Communication with supporting engineering operations and surrounding privet sectors and federal government offices would be enhanced through GIS implementation as well. Opportunities to determine spatial trends would become another benefit of GIS that would otherwise not be possible (Campbell and Masser, 1995).

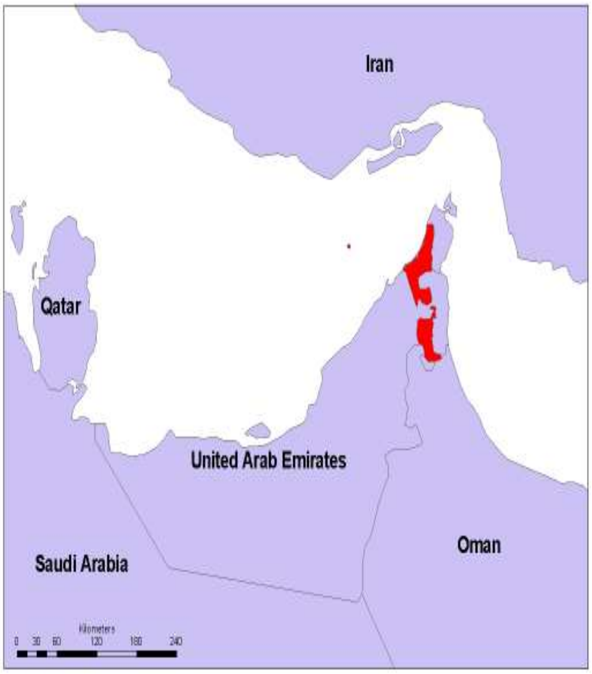

Figure 1. Location of Ras Al Khaimah – UAE.

By moving to the new technology, the Ras al Khaimah GIS project (RAKGIS) goal was to offer accurate data more efficiently to the public through ArcIMS applications and the Internet. The project was a multi-departmental collaboration that required new hardware, software, updating geospatial data, developing GIS applications and training. Upon completion of the GIS implementation, GIS data will be more accurate, more efficiently maintained due to new business processes, and easier to access (McGill, 2005). More people can access the GIS data including RAK local government departments, federal departments, and the public at large.

The technique of RAKGIS will play a very crucial role in planning and decision making for development of RAK. This paper outlines the implementation of a functional GIS for RAK. Beginning with a year-long RAK Emirate has developed a base-level GIS with Emirate data, executed training for local government staff, and is now in the process of implementing the turn-over of the GIS to the Emirate.

OBJECTIVE

The GIS infrastructure, which RAK Emirate wants to build, has some characteristics that are new to the Emirate. It affects the complete directorate (technical infrastructure, organization and work processes); Therefore, this research aims to review the current strategy of GIS implementation and discuss the implementation process constraints. The initial RAKGIS implementation strategy was to define the public originations requirements and then to plan and introduce the Emirate land information system.

IMPLEMENTATION PLANNING

Implementation planning refers to the process of translating the strategy into a series of specific project tasks; when these are completed, the organizations that plan to use GIS in RAK will have a functioning GIS (Reeve and Petch, 1999). The following are explanation of each step in implementation plan:

Cadastral Data

RAK already have considerable infrastructure and administrative systems for better management of land and resources. Basic information creation processes are cadastral surveying that identifies land and running a Digital Cadastral Database (DCDB) providing the spatial integrity and unique land parcel identification, registering land that supports simple land trading (buying, selling, mortgaging and leasing land); running a land information system (LIS); and GIS that provides mapping and resource information (Nancy, 2004).

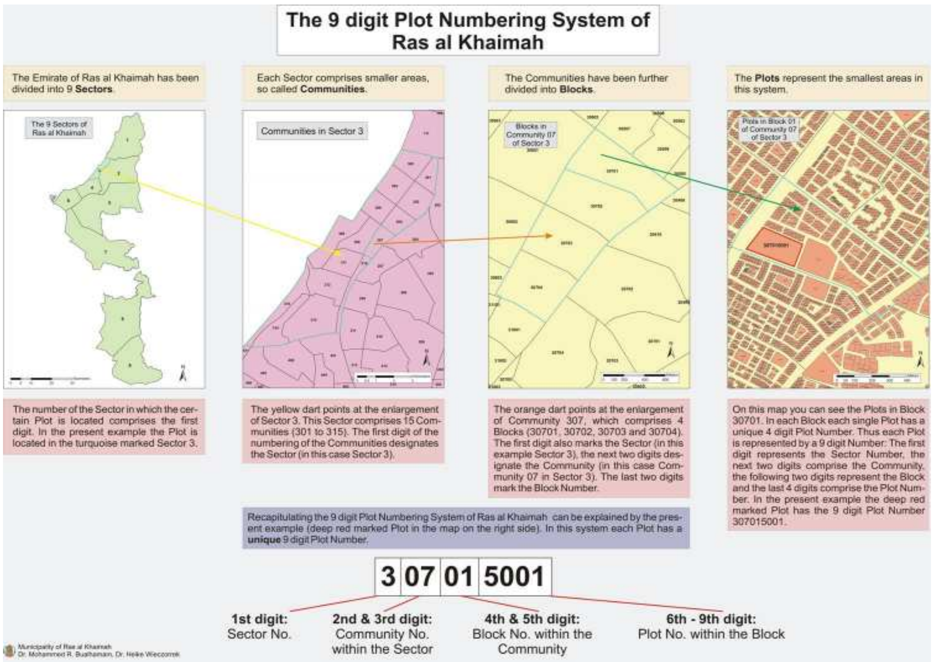

Figure 2. Unique Land Parcel Identification of RAK.

Typically, the unique parcel number (nine digit number) is used in the graphic environment as the link to the non-graphic data (Longley *et al*, 2001). The Emirate is divided into nine sectors and each sector comprises smaller areas, so called communities, in which exist ninety nine areas or communities in each sector. These areas have been further divided into blocks in which exist ninety nine blocks in each area, then into smaller plots in which exist nine thousand nine hundred ninety nine plots in each block (Figure 2). The parcel data should be matched to an accurate land base or digitized within an acceptable coordinate system (Dale and McLaughlin, 1988).

RAK emirate has a strategy to maintain cadastral data constantly. When the parcel mapping project is complete, ongoing maintenance becomes a priority (McGill, 2005). Parcel mapping is a contiguous process that should evolve toward increasing reliability and accuracy (Nedovic, 2000). These maps are never finished, and require constant updating to keep pace with cadastral transactions (Von Meyer, 2004). Parcels are complex features. To determine the overall geometric relationships, ties to physical geography, and historical and legal objects must be considered (Nedovic, 2000). Even the definition of what constitutes a parcel often varies widely. It is important, however, to stress the importance and use of the parcel in the GIS environment. Though reliability, consistency, accuracy, and precision are all important attributes of a parcel map, they should still be considered only a model of the physical and legal world, and not an exact replica (Slocum *et al*, 2005).

GPS Control Network Survey and Spatial Framework Design

The Enterprise GIS solution is based on the principle of providing a seamless framework that allows horizontal and vertical integration of GIS and abstracted information into a contiguous database structure (Waite, 2005). This necessitates the design of a Spatial Framework, and therefore the establishment of a contiguous GPS Control network that will allow for the spatial framework registration (Kadir *et al*, 1997).

The basic principle of Survey is to work from the whole to parts. As to carry out any survey, a basic reference framework needs to be established (Kadir *et al*, 1997). Also, a one-time activity of establishment of a GPS Framework across the RAK – a set of primary, secondary points in the Emirate that positions a 2-tiered network across the region. A one-time activity of establishing a GIS Framework using this GPS Network (with proper definition of datum, projection and coordinate system) - such that upstream the GIS Framework fits into the UAE Framework and downstream the GIS

Framework allows incorporation of all GIS records, images, land survey and other spatial data - thus enabling a seamless RAKGIS (Hofmann Wellenhof *et al*, 1998).

The spatial framework should be sufficiently accurate to allow integration of the existing spatial data as well as being able to be used as a basis for all future mapping and GIS activities of RAK (Longley *et al*, 2001). The following specifications have been identified:

1. Two levels of control points will be determined (Figure 3). Primary Control Points and Secondary Control Points. Primary control points should be traceable to external IGS Stations and the UAE Control Network to produce a seamless network. The level of accuracy of primary control points that have been linked to IGS stations and the UAE control network was specified. Secondary control points should be directly derived and traceable to the Primary Control Points.

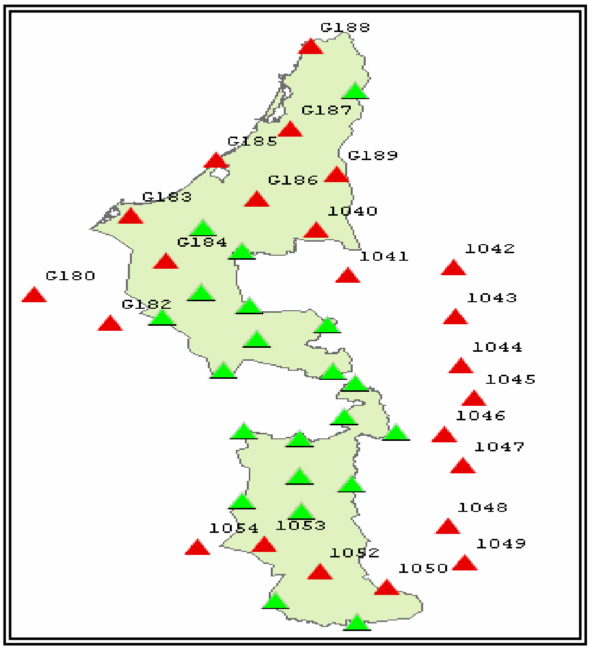

Figure 3. Primary and Secondary Control Points of RAK.

2. Sufficient Primary and Secondary Points will be provided to maintain the required accuracy throughout the survey area. The minimum radial distance between any two Primary Control Points will not exceed a nominal twenty kilometers (20km). Secondary Control Points will be established in every five kilometers radius.
3. Control network accuracy required for RAK is as follows:
   a- Primary Control Points will support an accuracy of 1:1000000
   b- Secondary Control Points will support a published accuracy of 1:100000
   c- Accuracies are to be quoted with reference to the IGS and existing UAE Survey Network.
4. Primary and Secondary control point coordinates are to be established using dual frequency survey quality GPS receivers, capable of logging static GPS data for post processing (Hofmann Wellenhof et al, 1998).
5. The horizontal datum for geographical data produced in the project shall be in the WGS 84 datum. The GPS coordinates should be supplied in both WGS 84 geographic coordinate system and also in UTM Zone 40 projection system. All points will be supplied with orthometric and ellipsoidal heights (Slocum *et al*, 2005).

Organising Seamless RAKGIS Using 2002 AutoCAD Map/Data

RAK is already having 2002 surveyed topographic maps, thematic maps, base maps and planning maps - that have been prepared at different times and in different projects. These maps are in different projection systems and datums which leads to a lot of shift in data and to confusion in carrying out many planning activities (Sawicki and Craig, 1996). Part of the strategic plan is to correct these maps and train the officials to carryout the exercise in the modified work plan (Eric *et al*, 2004). The main activity will be as follows:

1. To transform the existing base maps as AutoCAD drawings to the RAKGIS spatial framework.
2. To transform the existing planning maps available in Clarke datum to WGS 84 UTM projection.
3. To transform the existing orthoimages to the GPS reference framework, if not fitting well.
4. To transform any other map data available in digital format to RAKGIS Spatial framework. Incorporate Oracle-SQL based attribute data for all layers.
5. Delivering a comprehensive seamless RAKGIS database in the spatial framework.
6. Create Metadata for RAKGIS seamless database and develop a RAK-Metadata application service.

Aerial Survey for 2007, Enterprise GIS Mapping and GIS Database

RAK requires a series of digital map products (imagery, DEM, maps etc) that will provide update and additional value to the enterprise GIS and its use at the local, and the Emirate levels of government, as well as to the general public (Figure 4). Delivery expected from aerial survey are digital elevation models (DEM), contours and recent maps for whole RAK alongwith 2007 ortho-images in AutoCAD format. All raw data, intermediate products, survey data and documents for the aerial survey and mapping will also be delivered (Maantray *et al*, 2006). The final enterprise GIS database must contain 2002 GIS layers and updated 2007 GIS layers.

Also, RAK intends to have a three dimensional (3D) city model for its core urban area of RAK, on a pilot basis. An area of ~100 Sq. km would be identified for the 3D city modelling. On successful completion and integration with the Enterprise GIS, the same

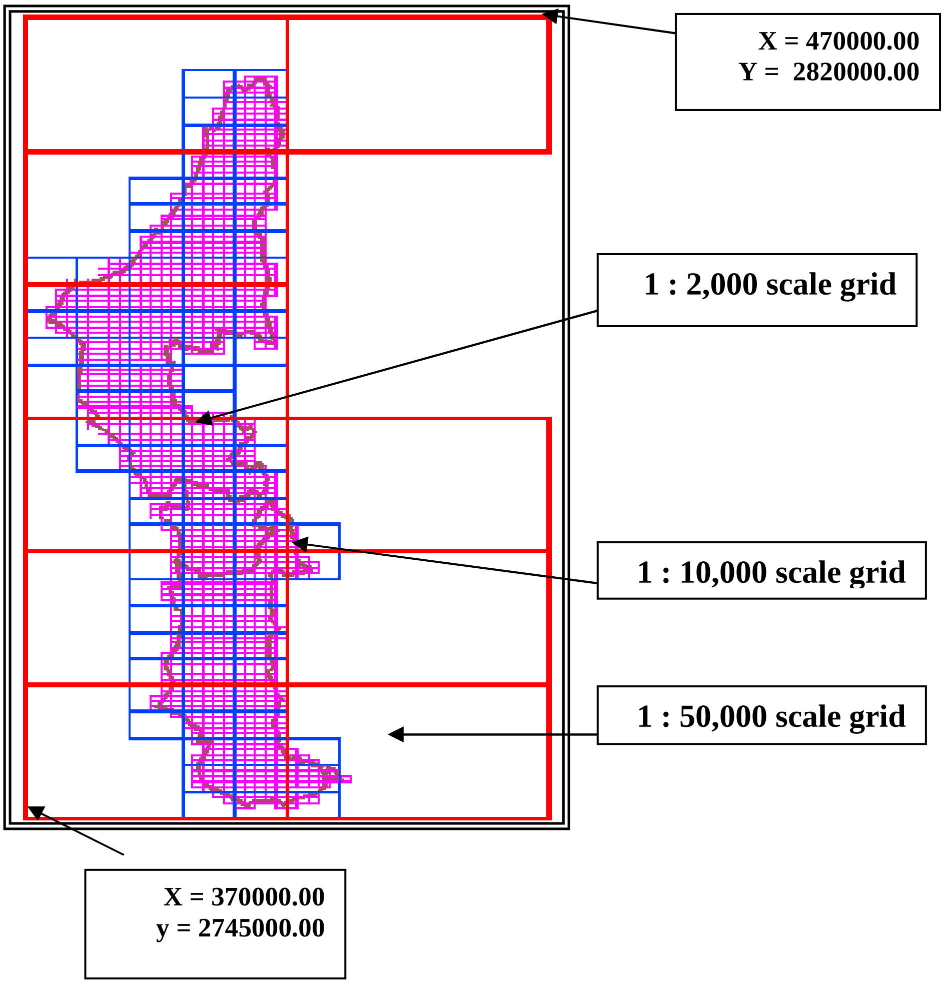

Figure 4. RAK Spatial Framework.

can be extended for more areas of the urban segments. This 3D city model is not just a Cad 3D but a true 3-dimensional city model (Slocum *et al*, 2005). However, the most important element is the integration with the enterprise GIS and the appropriate solution may be proposed (Juliana, 2006). The enterprise GIS will grow – grow with the need for updated datasets that will be acquired by fresh aerial surveys every two years for the RAK urban area and development of newer and newer applications for governance and citizens.

GIS Application Development

Application development is an integral part of GIS operations. It is the creation of the tools necessary to complete the goals and objectives detailed in the needs analysis (Longley *et al*, 2001). Introducing any application to each administration in the Emirate will emphasize the GIS's overall importance to these organizations, the degree of impact and visibility, and benefit of automation (Budic, 1996). The strategic development of applications that will enable staff to work more effectively. Almost all applications for all departments will be deployed. By developing custom-designed toolkits for geographic analysis, the RAKGIS delivers GIS technology to users who may not be GIS professionals (Campbell and Masser, 1995). RAKGIS applications were developed for the following main applications:

- Management application
- Twon planning application
- Sewerage Management Module

To provide users efficient data access and query capabilities, most systems require substantial amounts of application programming to occur (Reeve and Petch, 1999). Access to the information must be transparent to the civil servants that perform the operations on a daily basis (Elwood and Leitner, 1998). RAK has initiated development of eight GIS Applications as a pilot project which cover 9 percent of the

Emirate. The eight GIS applications for the pilot project include the following:

- General Map Handling Module- allowing for basic display and querying operations.
- Map Publishing Module- allowing for publishing displayed maps in standard templates.
- Site Plan Applications- allowing for applications, approvals and monitoring the building site plan applications.
- Land Information System (LIS) Module- allowing for land records applications.
- RAK Plan Module- allowing for Plan related actions on the RAK Plan data.
- Sewerage Management Module- allowing for basic management on sewerage network.
- No Objection Certificate (NOC) Module- which will allow applying and tracking NOC applications on land allotments.
- Project Tracking Module- which will be able to track the status of projects on-going in RAK.

The project also will develop eight GIS applications and link with the eight pilot GIS applications to deliver an integrated suite of sixteen GIS applications which will link to the RAKGIS framework using the ArcGIS server technology. These additional GIS solutions include the following applications:

- Signboards Management- which allows for planning, monitoring and maintaining all sign boards in the Emirate.
- Addressing and Routing Applications- allowing for address management of each property in RAK and generates driving

directions between multiple locations with route finding web services.

- Planning Conditions Applications- allowing for incorporating future plans and their status monitoring.
- Automation of survey services: to automate the process of Survey Department and delivering the surveying reports in a systematic and organized manner. Also, the reports generated as part of the survey service activities would be directly linked with the RAKGIS application.
- Integration of GIS with CCTV- for monitoring all CCTV systems.
- Fleet Management- for fleet management solutions for RAK logistics and service fleets.
- The Building Permit Approval (BPA) Module aims to facilitate the Building and Engineering Department, Municipality for issuing Building Permit Certificates (BPCs).
- Solid Waste Management- for environmental planning and monitoring of solid-waste sites.

Good GIS applications empower users even novice GIS users (McGill, 2005). Application customisation is often one of the most time consuming and expensive elements of implementing a GIS (Reeve and Petch, 1999). It is also one of the keys to a successful GIS. So RAKGIS implemented a complex enterprise system by develop stand alone applications and custom GIS functionality to fit the Emirate needs.

Hardware and Software

Hardware and software acquisition are too often the primary focus of GIS planning (Waite, 2005). GIS needs and objectives should be the primary focus and should guide hardware and software acquisition. Since there is no single set of hardware or GIS software to meet the needs fully, it is strategic that the GIS team and the users maintain a broad knowledge of existing facilities to ensure responsiveness to the needs (Campbell, 1996).

At the time, RAKGIS was in the process of making the full migration from manual drafting to Computer Aided Design Drafting (CADD). The popular CADD packages provided excellent automating tools, yet they fell short of fulfilling the informating role that GIS provided (Elwood and Leitner, 1998). Many of the basic GIS functionalities such as composite overlays, buffering, routing and networking, were not possible to perform with conventional CADD packages (Longley *et al*, 2001).

The appreciation of "GIS by ESRI" and its ArcGIS products was but a normal extension to RAKGIS enterprise. Therefore, the urge by RAKGIS to provide a "Total GIS Solution" reinforced by an organized technology transfer plan, and followed by building the appropriate indigenous resources, all of these forces worked synergetically to achieve this dramatic introduction of GIS into RAK (Fowler *et al*, 2004). The right hardware was selected to address the needs of the RAKGIS. Five servers for the project consist of the following:

Database Server (with a Redundant Server)

The database server would hold the actual spatial data of RAK. The spatial data would be populated in oracle spatial and accessed through the ArcSDE (ESRI, 2004). The data server will be a high-end system that will host all the data of the RAK enterprise GIS and allow seamless access (Greene, 2001).

The redundant server, at all times, will have a mirrored database of the RAK enterprise GIS so that it can be placed into operation if the main data server is down. At other normal times, the redundant server can be used for all back-end LAN operations (ESRI, 2004). The database server (and the redundant server) would hold the following software:

- Oracle
- Oracle spatial
- ArcGIS server: ArcSDE component (at ArcGIS 9.2, ArcSDE technology has been incorporated into ArcGIS server.

Application Server

The Application Server would hold the different applications for enterprise GIS of RAK. This server interacts with the Database Server to access the data (Leander, 2000). Apart from the metadata (which is also an application), the Application Server could hold various developed applications that allow integration of data and delivery of final solution (ESRI, 2004). The Application Server would also hold the ArcGIS server.

Metadata Server

The Metadata Server would maintain the metadata content. At a higher level, it links to Web Server, and at a lower level it links through (Server Catalogue) to Database Servers (ESRI, 2004). ArcIMS metadata service would sit on this server (ESRI, 2002).

Web Server

Web Server layer provides the single point interface for communicating with the enterprise GIS application, which in turn communicates with the Application Server and provides a "secure" access/entry to Data Servers (ESRI, 2004). The web server will host the IIS, along with application services (Yeager and McGrath, 2006).

Training

Building and operating RAKGIS will require full time staff with specialized skills. New staff may be hired or contracted, and existing management and staff will require education and training (Harris and Weiner, 1998). The related activities must be scheduled and performed in concert with technical and other management activities (Reeve and Petch, 1999).

Apart from RAKGIS, staff are being trained in the use of this highly complex technology. Sufficient time should be allowed to enable training to be effective (Budic, 1996). If the time allowed for training is too short or is not pitched at the correct level to suit the user, adequate comprehension of this complex technology will not be attained (Waite, 2005). Training will be offered during the implementation and will be in many sessions. The training will focuses in the following aspects:

- Orientation module for senior professionals: this should include broad overview and concepts of GIS, broad functionalities of ARC Suite, broad functionality of GIS applications and operations, aerial photography, LIDAR, photogrammetry.
- Operators module: to provide details of GIS, Arc Suite and details of GIS applications and details of usage of the applications.

These training will offer by contractor. In addition, the government of RAK has signed a contract with the University of Heidelberg in Germany to give training to RAKGIS staff. Furthermore, the UAE University and some private GIS companies in the UAE will provide their training services.

CONCLUSION

To maximize the value of GIS in RAK, the implementation strategy needs to be reviewed and modified to meet old and new objectives of GIS and to go with a new trend of the technology. Now a days for a successful GIS the real needs are; users willing to participate in the implementation, training and use of the system; and knowledgeable staff to implement and operate the GIS. With the implementation of RAKGIS, RAK Emirate will have an accurate, spatially correct database and new methods for keeping the data more current than in the past.

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