USAGES OF GIS TECHNIQUES IN "A BALANCED SPATIAL DEVELOPMENT APPROACH FOR 3RD GENERATION PLANNING PROJECT OF THE BENGHAZI REGION"

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Key words: Geographic Information Systems (GIS), Regional and Urban Planning, Spatial Analyses, 3rd Generation Planning Project (3rd GPP)

I. SUMMARY

The 3rd GPP is a huge project which includes producing the base maps of Benghazi Region by using aerial photography, satellite imagery and field surveys, collecting the descriptive information from many sources, coordinating the institutions, considering new investments and projects, consulting the institutions, preparing regional and urban plans. All these issues force the project team to use some new approaches both in planning and technology.
Geographic Information Systems (GIS) is being used as the main platform for organization of all data and information. A spatial database has been created and is being used by the project team in order to better the planning decisions.

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II. INTRODUCTION

The 3rd Generation Planning Project (3rd GPP) is a series of planning processes initiated by the Urban Planning Agency (UPA) in partnership with the United Nations Human Development Program (UN-Habitat).The 3rd GPP covers the period: 2006 – 2025, with an aim to prepare relevant policies and physical development plans at national, regional, sub-regional and urban levels starting from metropolitan areas and extending down to small settlements.

Geographic Information Systems (GIS) is one of the main tools which is widely applied as decision aid in this project. GIS applications have frequently been used in producing new information by combining available and acquired data and information from diverse sources and spatial analyses. GIS has been structured on a huge spatial database (geodatabase) for many kinds of data collection works to function as a cartography tool for each scale (1/250,000; 1/25,000; 1/5,000; 1/1,000) as a spatial analyst for determining development directions, as facilitator in identifying appropriate locations for land uses and service areas as well as understanding surface properties in connection with technical infrastructure projects.

III. 3rd GENERATION PLANNING PROJECT (3rd GPP)

The People's General Committee for Planning and the Urban Planning Agency (UPA) recognized that there is a need for a new planning program to complement the 2nd GPP. The new planning program, known as the 3rd Generation Planning Project (3rd GPP), was deemed practical due to:

- The continuous growth of population, especially in the large urban centers;
- The emergence of new potentials that will affect the spatial development, such as the Great Manmade River Project and the Railway Project as well as initiatives of new investments and industrial enterprises;
- The opportunities to diversify the base of economic activities, such as tourism, foreign investments and the public-private partnership;
- The improvements in education and vocational training sector;

and most importantly,

- To regain control of planning in Libya and lay the foundations for the next stage of the country`s development.

IV. LOCATION

The Great Socialist People's Libyan Arab Jamahiriya is located at the centre of North Africa along the Mediterranean coast. Geographically, it is at a strategic location with potentially good linkages to Europe, Central Africa and the Middle East. Tunisia, Algeria, Niger, Chad, Sudan and Egypt are the border neighbors of Libya in Africa (Figure I).

Figure I: Satellite Image of Libya (**Source:** Google Earth Image, accessed in October 2010)

The Benghazi Planning Region lies between 19°50' and 25° east longitude, and 28°00' and 32°55' north latitude (Figure II) of Libya. It is situated in the north-east of the Great Jamahiriya being bounded to the east by the Arab Republic of Egypt, to the south and south-west by Al Khalij Sub-Region, and to the north and west by the Mediterranean.

The region covers an area of approximately 135,2701 square kilometers, which is 7.6% of the total area of Libya. A great part of the region, in the south, is known as the Great Sea of Sands where over 90% of the area is not populated. Benghazi is the most populated city in the region with over half a million inhabitants in 2006. It is the second largest settlement in the country after Tripoli and the largest urban area in the Benghazi Planning Region. There are

also four mid-sized cities in the Region, namely: Tubruq, Darna, Al Bayda and Al Marj, with populations varying between 60,000 and 110,000 in 2006.

Figure II: Libya – North Africa, Mediterranean
(**Source:** GIS database)

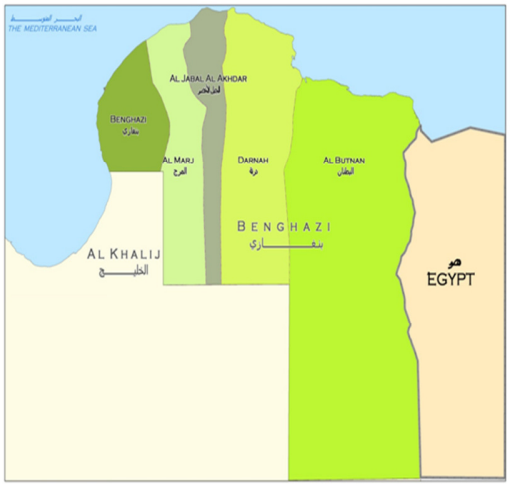

Figure III: Administrative Divisions of the Benghazi Region

Administratively, the Benghazi Region consists of the municipalities (Shabiya) of Benghazi, Al Marj, Al Jabal Al Akhdar, Darna, and Al Butnan **(Figure III)**.

V. APPROACH to PREPARATION of the BENGHAZI PLANNING REGION DEVELOPMENT PLAN (BPRDP)

Preparation of the BPRDP started with an extensive field inspection survey to document the existing conditions in the Region. An esteemed group of experts managed and supervised the surveys and studies and prepared reports on subjects as Geology, Climate, Natural Structure, Water Resources and Water Supply, Agricultural and Pastoral Development, Marine Resources, Environment, Energy, Population, Labour Force, Housing, Tourism, Spatial Features, Trade and Services, Industry and Transportation.

Important milestones of preparation of the BPRDP are as follows:

- Survey of existing conditions and data collection by Al Emara Consulting Office;
- Local Experts assignments to produce detailed sector reports (Al Emara Sector Reports 2005);
- Documentation of policies from previous studies and plans including National Economic Strategies (NES) and National Spatial Policy (NSP) as well as

assessment of 2nd GPP and other specific sector studies at national and regional levels; i.e. tourism, industry, agriculture, utilities;

- Submission of a draft report on the "Existing Situation of Spatial Development of the Benghazi Planning Region" in March 2006;
- A series of Methodological Framework Reports explaining a dynamic and interactive population forecast model, spatial distribution of settlement functions: functionality and sustainability principles, prioritization policies and standards for action areas as well as recommendations for institutional strengthening of planning in Libya.

VI. PURPOSE and SCOPE

The purpose of the planning process was to develop a framework that provides an integrated approach to planning and managing the future growth and development of the Benghazi Planning Region. The primary goals were:

- to provide an integrated approach to the planning and governance of the whole region;
- to devise strategies to improve the region's environmental and social development while diversifying its economic base; and
- to position the region for maximum competitive advantage and sustainability in its future.

Plans and projects of the 3rd GPP are expected to be **flexible** and **responsive** to steadily changing factors in a dynamic society in order to be interpreted with due regard to new conditions for undertaking appropriate steps. In this context, the 3rd GPP must be a device and an **instrument** for **managing** the **change**. This different outlook and novel expectations of The 3rd GPP urges adaption of modern and authentic planning methods and techniques particularly tailored and designed for Libya (3rd GPP, Benghazi Regional Report).

VII. USAGES of GIS in the 3rd GPP

VI.1. Geodatabase Design

A comprehensive geodatabase design has been achieved with contributions of the UPA and UNDP in order to carry out the needs of a multi leveled planning project. The main datasets of the geodatabase are shown in Table I. In addition to these datasets, all other relevant materials such as projection and datum information, symbology, hardcopy layout templates, etc. have been inserted to the database design.

Table I: Compiled and Stored Data (3rd GPP Benghazi Planning Region Geo-datasets)

3GPP BENGHAZI PLANNING REGION GEODATASETS
Satellite Images • LANDSAT images as rectified and mosaicked (1/250,000-1/100,000 at 15 m resolution) • SPOT -5 images as rectified and mosaicked (1/25,000 at 5 m resolution) • QUICKBIRD images as standard products and mosaicked (1/10,000 – 1/5,000 at 0.6 m resolution) • GEOEYE images as rectified products (1/5,000 – 1/1,000 at 0.5m resolution) Aerial Photographs • Digital Orthophoto images from AERIAL PHOTOGRAPHY (1/5,000 at 0.3 m resolution) • Digital Orthophoto images from AERIAL PHOTOGRAPHY (1/1,000 at 0.1 m resolution)
Topographic Datasets 1/250,000, 1/25,000 digital topographic mapping • Transportation (Road, Air Transport, Marine Port, Railway) • Boundaries • Built-up Areas (Minor Settlement, Urban Area, Mixed Urban Area, Industrial Area, Archaeological Area) • Hydrology (Coastal Line, Wadi, Valley, Spring, Lake) • Relief (Contour, Spot Heights, Escarpment, Volcanic Crater) • Technical Infrastructure (Oil and Gas Pipe Line, Oil and Gas Field, Energy Supply, High Voltage Lines, Electric Transmission Substation, Power Plant, Desalination Plant, GreatManMadeRiver, Water Supply Reservoir, Sewage Treatment Plant, Communication) • Landcover (Agriculture, Grassland, Scrubland, Bare Rock, Bare Land, Forest, Sabkha, Sand Dune, Oasis, Other) 1/5,000 and 1/1,000 digital topographic mapping (Linemaps for all settlements) • Land use • Land cover • Transport • Technical Infrastructure • Relief • Hydrology • Other

Thematic Datasets

1/250,000, 1/25,000 digital topographic mapping

- Traffic (Busnet, Public Transport)
- Environment (Airport Noise Zone, Groundwater Basin, Solid Waste, Drainage Area, Groundwater Decline, Seawater Intrusion, Sewage Discharge, Polluted Area)
- Meteorology (Temperature, Rainfall)
- Landscape (Tourism Area, Protected Landscape, Mineral Resource, Desertification, Fauna, Flora, Natural Park)
- Relief (Contour, Spot Heights, Escarpment, Volcanic Crater)

Planning Datasets

Previously approved plans at national, regional, sub-regional and urban levels in particular 2nd GPP plans at all levels.

Other Datasets

- Geology
- Building Inventory
- Road Inventory
- Investments and Projects

VI.2. Spatial Analyses

Various spatial analyses have been carried out within the 3rd GPP such as identifying Sustainability Pattern, Creating Buffer Zones, Figuring out Surface Properties, and Determining Service Areas for social institutions, etc. by using the GIS environment.

VI.2.1. Determining the Sustainability for Development Areas

3rd Generation Planning Project of the Benghazi Region has necessitated incorporation of sustainability approach into spatial planning at almost every scale. Following a top-down strategy, a balanced development based on sustainability principle aiming at conflict minimization approach is developed and integrated into spatial planning at regional scale (1/250,000) and at sub-regional scale (1/25,000). This could avail a solid basis for further extension of the sustainability principle into spatial planning at master plan (1/5,000) scales.

It was an attempt for modeling and incorporating sustainability approach into spatial planning for design of sub-regional spatial plans and strategies. It traced the environmental aspects of sustainability by relying on a suitability analysis, which took into consideration the Region`s immense natural environment for protection and investigated potential locations for hosting new developments. In this context, advanced GIS technology has been used to perform spatial analyses and to create suitability map based on evaluation of multi-criteria to determine appropriate land use schemes in the Region.

Suitability Pattern Analysis is regarded as an instrumental aid for a strategic decision making to **prevent abuse** and **profligacy** in planning as well as **to promote cost minimization** and **achievement maximization** intentions implying that **rationality principle** has to be applied with due regard to **sustainability principle** while new developments are taking place in the Region.

Suitability Pattern Map is a result of overlaying weighted multiple variables and it presents likelihood of occurrence of effective variables and their spatial formation in order to determine areas where development can take place without causing any conflicts in landuse.

VI.2.1.1. Principal Stages in Suitability Analysis

The Suitability Analysis process started with the designing a questionnaire to avail the participation of the experts in the survey. The questionnaire form included four main components as indicated below;

(i) Technical infrastructure component including main roads, GMMR and other essential water reservoirs as well as high voltage lines are used to determine "accessibility" to major infrastructure facilities.

(ii) Natural feature component comprising land cover, earthquake fault-lines, hydrology, geology, soil classification, protection zones, flora and fauna are referred for defining conservation and protection zones where natural landscape is more fragile and sensitive. These were also referred for defining areas where development should be either limited or needed however under certain measures prior to realization of any action.

(iii) Slope and topographic soil wetness indices were used for identifying suitable areas in regard to native flora and fauna of the Region where development should be avoided. In addition, these were used for identifying areas where development is rather difficult but can be achieved with gradual or incremental undertakings.

(iv) Lastly, the analysis included built-up areas, population size of settlements and their previous plans (2nd Generation Planning Projects) with development boundaries as well as the State sponsored agricultural project areas. The final component was an attempt to encourage optimization of present land use and to prioritize residual areas of current urban fabric as well as development areas of previous plans in urbanization process. It assumed that settlements with relatively adequate size in terms of population would better attract and absorb new developments. In addition, the State sponsored agriculture projects areas were subjected to protection and better utilization.

A group of experts mainly from disciplines of urban planning, environment and geography were asked to weight main variables and their sub-types presented in aforementioned survey form. The experts' weighted multi-criteria evaluation for incorporating in the GIS based spatial analyses which performed combination of spatial information from different sources and data layers. This process included followings steps;

- Determining weight of main variables and their sub-types; this has helped to identify the effective factors and their importance as multi-criteria evaluation of the experts have been compiled from the questionnaire forms.
- Producing map layers based on the experts` evaluation; Through GIS technology, Multi-Criteria Evaluation method has been used for creation and combination of different map layers and information from various sources.
- Performing the Suitability Analysis; This included cartographic modeling of the spatial data and production of suitability maps of the Region at 1/25,000 scale.
- Clustering Suitability Pattern Indices and producing final outcome; this was the end product and output of the process.

The averages of the weights of main variables are given in Table II.

Table II: A List of Main Variables and their scores

Main Components	Main Variables	Average of Weighted Values by the Experts
1. Assessment of Accessibility	Main roads	3
	Water reservoirs	4
	Transmission lines	3
2. Assessment of Natural Land Features	Land cover	13
	Earthquake Fault Lines	4
	Protection Zones	10
	Hydrology	8
	Geology	2
	Soil Types	7
	Flora	7
	Fauna	5
3. Assessment of Landform	Gradient	4
	Topographic Soil Wetness Indices	4
4. Landuse Optimization	Built-up Areas	6
	Previous Plans` Development Areas (2nd GPP plans areas)	7
	Settlement Population Size	3
	Agricultural Project Areas	10

Since each main variable is a map layer in GIS, it consists of more than one sub-type as attributes. For example, landcover map of the Benghazi Region was classified as bare rocks, bare lands, sand dunes, meadows, scrublands, agricultural lands, forest, wetlands, and others. These are the sub-types of the `landcover` variable, which is incorporated in the Suitability Analysis for assessment of natural land features. Similarly, main roads are classified as regional, sub-regional and arterial roads, which are the sub-types of variable of the main roads. This holds also for rest of the main variables.

Usually a spatial analysis based on Multi-Criteria Evaluation, especially those using quantitative and mixed data sources (Tunca, 2003), requires some form of standardization of the scales of measurements associated with variables and their sub-types. This is necessary to facilitate the comparison of measured factors by using different units and scales of measurement.

Both minimization and maximization functions take values between 0 and 1 when weighted value of a variable is standardized. The choice of whether to maximize or minimize the weighted value depends on how impacts of the variable are estimated and judged, and it depends whether to permit or restrict the developments.

$$\text{E1:} \quad Minimization\ (Xi) = \frac{Xmax - Xi}{Xmax - Xmin} \quad and,$$

$$Maximization\ (Xi) = \frac{Xi - Xmin}{Xmax - Xmin}$$

Once the standardized value is calculated for each sub-type of the main variables, it has been then taken as a coefficient for multiplying by the experts` in order to reach weighted values for the main variables and to define relative priority of the suitable sites for new development. This process is carried out for all sub-types and main variables. Subsequently, the results are combined with GIS technology and represented on the Suitability Pattern Map of the Region.

Combining the factors has been done by relying on multi-attribute utility theory (MAUT) and accomplished by an additive priority function P that is expressed as an equation shown below:

$$P = \sum_{i=1}^{m} a_i\, p_i\, (q_i)$$

where P is the global priority, i.e. conservation site suitability index; m is the number of factors, a_i is the relative importance of factor i ($\Sigma a_i = 1$); p_i is the sub-priority function of factor i; the maximum value for each factor is one; and q_i is the amount of factor i.

VI.2.1.2. Results of Suitability Analysis

The Suitability Pattern Map is a representation of values, which are standardized according to the experts` weighted values for each variable incorporated into the analysis. These have been measured as between 12.26 and 87.82 (Figure IV) which are also needed for clustering the values for better understanding of and communicating with the Suitability Pattern. As a result, interval between 12.26 - 40.4 stands for **"Low Suitability-L"** where natural and man-made environments offer the least appropriate formation for new developments. As 40.41-49 stands for **"Low to Moderate Suitability-LM"** and 49.1-55.3 stands for **"Moderate Suitability-M"**, 55.31-60.7 stands for **"Moderate to High Suitability-MH"**, while 60.71-87.82 stands for **"High Suitability-H"** where both natural and man-made environments availed the most appropriate formation for new developments.

The result of this analysis has been carried to settlements level in order to assist identifying the development characteristics of them, individually. The results are given in Table III.

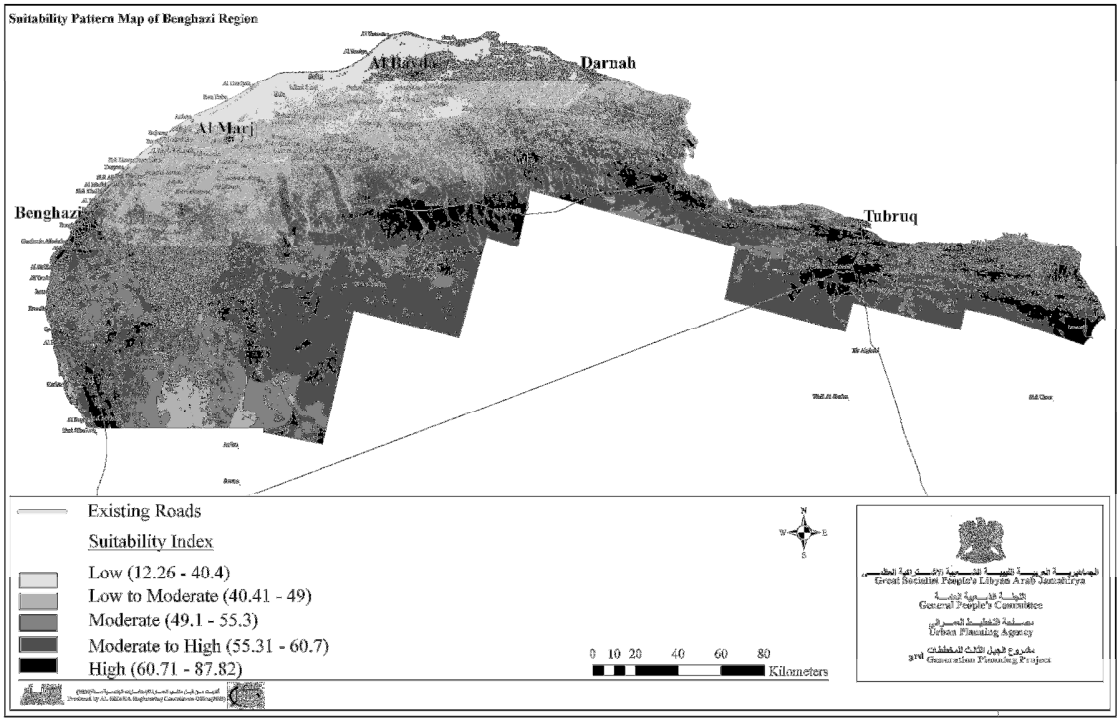

Figure IV: Suitability Pattern Map of the Benghazi Region

Table III: Benghazi Sub-region: Ratio of L, LM, M, MH and H Areas

Subregion	**Settlements in Sub-regions**	**Land Suitability Around Built-up Areas of the Settlements (%)**				
		H	**MH**	**M**	**LM**	**L**

Benghazi	Benghazi	29.80	46.74	16.97	5.82	0.66
	Al Abyar	14.34	34.55	37.77	12.85	0.49
	Banina	1.62	38.31	48.57	11.50	0
	Qaminis	29.45	60.51	10.04	0	0
	Solouq	50.95	46.32	2.73	0	0
	Tukra (Al Aquriya)	0.01	0.12	9.91	42.67	47.30
	Sidi Khalifa	2.80	12.25	17.72	42.47	24.77
	Al Khadra	5.64	29.87	64.49	0	0
	Al Magroun	77.95	22.05	0	0	0
	Al Nawaqia	7.61	82.10	10.29	0	0
	Al Rajma	1.84	25.49	51.13	21.54	0
	Bumaryam	1.49	32.68	57.65	8.16	0.02
	Deryana	0.01	0.12	9.91	41.81	48.15
Al Marj	Al Marj	1.26	7.85	21.75	66.42	2.72
	Al Bayadah	0.02	0.20	4.82	89.28	5.68
	Al Darsiyah	0	0.06	4.03	26.74	69.17
Al Jabal Al Akhdar	Al Bayda	5.26	3.45	11.12	50.51	29.66
	Shahhat	2.76	3.10	11.88	53.85	28.4
	Al Abraq	0.72	0.82	11.73	59.96	26.77
	Massah	0.11	0.49	1.48	21.53	76.39
	Susah	0.34	1.15	7.17	45.80	45.55
	Werdama	1.15	2.76	11.24	57.82	27.03
Darnah	Darnah	13.96	19.07	24.69	32.06	10.22
	Al Qubbah	1.00	1.61	16.92	46.73	33.74
	Martuba	11.03	64.21	23.42	1.34	0
	Al Atharun	0.03	0.11	0.41	22.97	76.48
	Ras al Hilal	0.05	0.17	1.71	31.68	66.39
Al Butnan	Tubruq	65.44	22.76	11.43	0.36	0
	Al Adam (Omer Al Mokhtar)	96.14	3.86	0	0	0
	Imsaad	98.76	1.24	0	0	0
	Al Burdi	55.60	32.19	11.50	0.72	0

VI.2.1.3. Consequence

The scarcity of ecological assets and natural resources, which are mainly limited to Mediterranean corridor in the Benghazi Region, require precautious scientific approaches in planning and implementation as well as effective enforcements in practice.

The results of sustainability study and also some other inputs of planning approach guided the project team to create development scenarios for each Sub-region and the settlements, individually. The determined strategic planning models for the main characteristics of the Sub-Regions are:

–Metropolitan and Agropolitan Development Model for the Benghazi Sub-region,

–Sustainability based Development Model for Al Marj and Al Jabal Al Akhdar Sub-regions,

–Self-sufficiency based Development Model for Darnah Sub-region and

–Growth-Pole based Development Model for Al Butnan Sub-region.

VI.2.2. Analyzing the Surface for Technical Infrastructure Projects

The technical infrastructure projects consist of three main parts: Water Supply, Sewage and Drainage, Power Supply.

Water Supply along with Sewage and Drainage Systems are highly related with the morphology of the surface. To decide whether "gravity flow" or "pumping flow" networks will be used depends on the surface properties which include flow directions, flow accumulation, slope and elevation of the location. All these features have been analyzed by GIS availabilities. The main principles of these steps are graphically shown in Figure V.

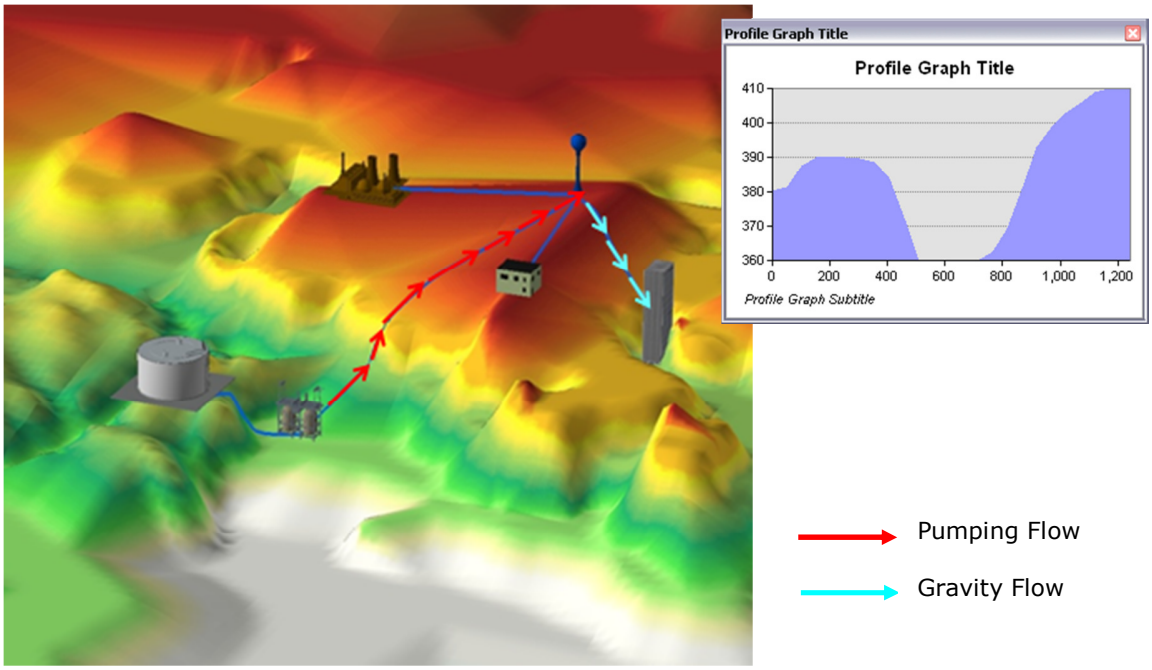

Figure V: Surface Properties for “gravity flow” or “pumping flow”

VI.3. Data Collection

Mobile GIS opportunities have been used in order to carry out the works for creating the Building and Road Inventory. The software has been customized, as shown in Figure VI, regarding the needs of the field works. Afterwards, base maps and aerial photos have been copied to Tablet PCs. A training course has been organized for the field surveyors after establishing the Tablet PCS, software, data and methodology.

The attributes, which are mainly useful for implementation plans at 1/1,000 scale, collected from the field are:

For BUILDINGS

Construction Material (Concrete, Stone, Brick, Mud, Wood, Other) - Condition of Building (Good, Medium, Bad, Ruined, Under Construction) - Number of Floors - Terrace (Yes / No) - Out Buildings (Yes / No) - Number of Units - Number of Residential Units - Number of Empty Residential Units - Number of Non-Residential Units - Commercial Type (Alimentary / Professional Services / Other Trade and Services / Entertainment and Accommodation / Workmanship) – Explanation - Date

For ROADS

Road Name - Number of Lanes - Road Condition

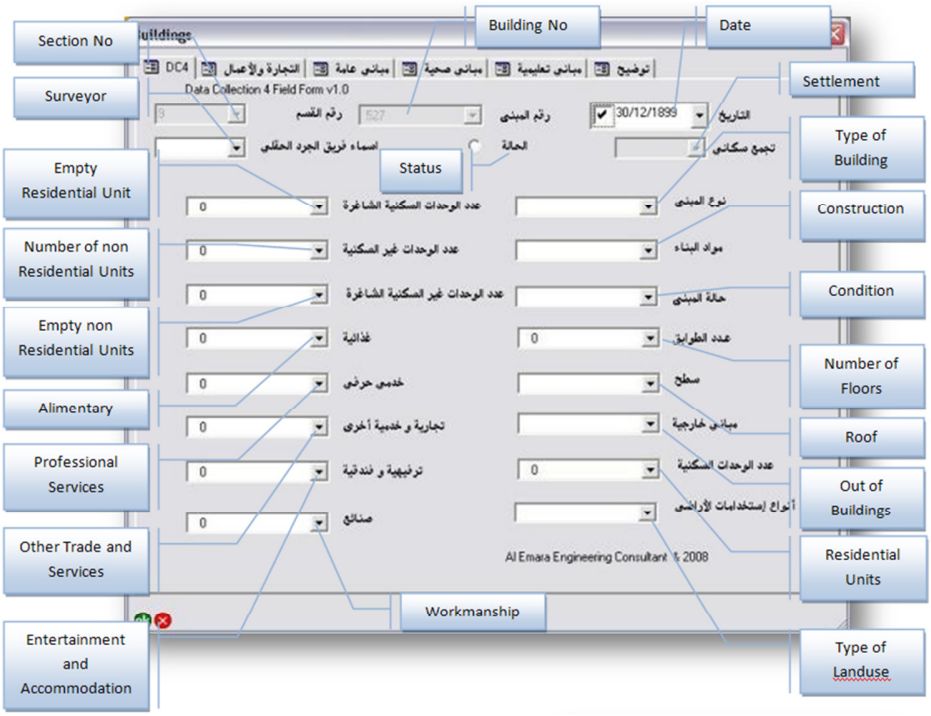

Figure VI: Interface of Developed Application

VI.4. Cartography

One of the main opportunities in GIS is to create powerful cartographic products. GIS avails to assign any type of attributes to spatial features. Implementation of the produced and/or analyzed data can easily be done using many options such as working layer by layer, creating symbology, making dynamic graphs (bars, pie charts), gathering statistical information, etc. The combination of all these opportunities helps to prepare effective, and meaningful map products.

Benghazi Metropolitan Area plan at 1/25,000 scale, is presented on Figure VII. The main land use decisions, population projection, surrounding relationships, surface properties, and transportation opportunities are shown on the same product.

Figure VII: Cartographic Output at 25K

Figure VIII: Cartographic Output at 5K

A part of Benghazi Metropolitan area plan at 1/5,000 scale, is presented in Figure VIII. Land use decisions in more detail when compared with 1/25,000 scale have been produced using GIS opportunities. The statistical information such as areas of land uses; number of schools, hospitals, etc.; existing and projected population for each residential area are used to form the plan more accurately.

The final stage of 3rdGPP is to prepare Implementation Plans at 1/1,000 scale. A sample of Implementation Plan is presented in Figure IX. At this stage, all the decisions were carried on a more accurate base (orthorectified aerial photos and linemaps) and more details such as plots and their numbers, parking areas and their capacities, etc. are indicated.

Figure IX: Cartographic Output at 1/1,000 scale

VIII. CONCLUSION

As a multi-disciplinary field, Regional and Urban Planning needs the involvement of many professions which makes it a complex process. The complex characteristic of Regional and Urban Planning requires however effective management. Researching, developing, implementing, and monitoring stages in the planning stages are the main steps which can be organized in a GIS environment with more accuracy and high accessibility. These kinds of opportunities provided by GIS help planners to better planning proposals and decisions at each scale and platform.

Creating and editing along with visualizing and querying the data, preparing various types of map outputs and presentations, supplying reports, elaborating the statistical information, analyzing the surface properties, assessing the environment, etc. are the main skills of GIS which are all needed in a thorough and integrated planning process.

Participation of citizens, institutions, social groups, in the planning process is another relevant aspect that avails the planners and decision makers to deal with more widely accepted planning proposals and decisions. At this stage; in addition to collecting, compiling and analyzing the data, also sharing it, which can be done via diverse channels including internet, plays an important role for efficient feedback mechanisms and synergy creation.

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X. BIOGRAPHICAL NOTES

Dr. Orhan Ercan
He was born in Turkey at 1959. He had his BSc at 1983, MSc at 1988 and PhD at 1997. He had worked at the Geodesy, Photogrammetry, Cadastre departments of General Directorate of Land Registry and Cadastre. He executed the World Bank`s MEER/MERLIS and ARIP/Cadastre projects. He worked as executive staff at `Turkish National Spatial Data Infrastructure Project and phase I and II` of Land Registry and Cadastre Information System. He worked at CORS-TR project group. He had published more than 30 papers for various academic publications. He works for GeoTech Group as Vice President.

M.Sc. Adem TUNCA
He was born in 1976 in Turkey. He has been graduated from the Department of Regional and Urban Planning (Gazi University, 2000, Ankara-TURKEY) and had his master degree on Geodetic and Geographic Information Technologies (Middle East Technical University, 2003, Ankara-TURKEY). He has experiences on various types of projects such as establishing urban management systems and address information systems, creating digital inventories, determining crop patterns (GIS and RS), nature conversation, regional and urban planning, etc. He is working as the Head of GIS Division in 3rd GPP of Benghazi Region in Libya.

XI. CONTACTS

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