Transforming the Conventional Graphic Layouts of Civil Infrastructure into Geospatial Themes for Urban Management

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ABSTRACT

The current research effort describes the strategy of transforming graphic sketches of urban infrastructures, prepared by the pertinent organizations according to their respective needs, to thematic information following a common geographic reference. Attention could have been rendered to exploit geospatial technologies at multi-organizational strata in Pakistan, by using GIS applications.

One of the most significant of which involves developing a geospatial database of administrative setups responsible for this planning and management of urban infrastructures for providing civic amenities to the citizenry at large. The achievement of the goal started with the need assessment of administrative organizations involved in planning and management of the urban environment.

The road network, water supply, power distribution, telephone connections, sui-gas distribution, sewerage outlets, educational and health facilities, police stations, post offices, fuel stations, banks, ATM facilities, emergency response centers, commercial areas, religious sites, and revenue zoning areas are among the major elements of civic infrastructure that were taken into consideration. The RS/GIS techniques were found very useful for the mapping and study of geospatial features of the Urban Environment and their respective attributes for analyzing their interactive characteristics.

(Keywords: thematic information, GIS, urban, geospatial technologies, Remote Sensing (RS), Environment, urban planning)

INTRODUCTION

Lahore is the provincial capital of Punjab and the second largest city of Pakistan with present population of about 6.32 million (Ijaz Ahmed & Ihsan Ullah Bajwa, 2004). Its population has increased from 0.85 million in 1951 to 5.2 million in 1998 (Census 1998), which reflects tremendous increase making it more congested than ever. The expansion process is still continuing both due to its own population expansion and the influx from surrounding areas. Understanding the growth and change brought on by urbanization is critical to those who must manage resources and provide services in these rapidly changing environments (Yang 2003).

The rapid population growth has caused heavy pressure on city administration regarding issues of transportation, atmospheric pollution, water supply, sewerage, electric power and other civic amenities with impacts to the citizenry at large. Since, the provision of most civic services to the public involves geographic aspects (i.e., locate and provide) there is a logical need that all the agencies responsible for providing basic urban facilities to the citizens should have accurate maps, rectified to a common geographic reference for use in the urban environment.

Unfortunately, hand-made sketches of civic infrastructure without any grid reference are being developed and used by each agency for the achievement of their respective goals. Moreover, maps are seldom updated after any specified time-interval. Resultantly, there is non-conformity in the precincts of various administrative divides depictive of Town, Union Council, and Population Census units.

Another drawback of developing and using hardcopy sketches is that such maps can not be shared among administrative agencies, owing to the arbitrary scales, paper sizes, annotations and orientations. The problems are getting complex in the absence of the use of modern techniques for handling geospatial information of civic interest.

In present research, an urban model has been developed that suggests the use of Remote Sensing (RS) and Geographic Information Science (GIS) techniques for preparing an urban geo-database where geospatial information is developed systematically in coordination with administrative organizations. This information can then be used and shared interactively among those agencies. Where to get data for urban planning and management is one issue but how to manage this data is still a more challenging task (Raza and Kainz, 2000).

An effort has been made to address both of these issues. The idea is to suggest such a system where geospatial database could not only be easily accessed and effectively used but would also have the flexibility of being updated on the basis of mutually agreed upon time frame.

Geoscientists and planners have increasingly been exploiting various tools of GIS for the development of Geospatial Information Systems to manage both the Urban and Rural Environments effectively, especially in the developed countries of the world since 1970. GIS possesses a performance record in handling urban information, especially in the field of urban planning (Brail & Klosterman, 2001; Han & Kim, 1990; Laurini, 2001, Zaki, 1998).

In Pakistan, GIS is not very new and owing to the scarcity of academic resource at institutional levels, its benefits remained mis-comprehended. Therefore, the hierarchy of higher management in disparate public sector organizations is mostly deprived of the fruits of GIS involving precise planning, designing, analyzing and management. With the inception of the modern era of information technology and wide-spread use of image processing and GIS techniques in developing a broad spectrum of geo-specific applications, Pakistan has recently started participating in developing geospatial applications both for research and projects at academic, private, and public sector institutions.

Relatively lower cost and easier availability of multi-temporal, multi-resolution and multi-sensor, and multi-platform satellite image data; faster innovations in computer hardware and software systems; and more trained manpower resource obtainable in GIS related fields, in comparison to what existed two decades ago, have not only promoted the understanding of geospatial technologies among planners and users, but also have augmented progress in these technologies.

Less attention could have been rendered to exploit geospatial technologies at multi-organizational strata. There still remains a significant need for developing a geospatial database of administrative setups responsible for the planning and management of urban infrastructures for providing civic amenities to the inhabitants.

LOCATION AND DESCRIPTION OF THE STUDY AREA

The geographic location of Lahore city is 33°34' North Latitude and 74°22' East Longitude, encompassing a total district area of 1772sqkm. The administrative divisions of the city comprise 2-Tehsils, 6-Towns, and 150-Union Councils. The study has been focused on the Gulberg area of the Lahore city, covering an area of about 16sqkm (Figure 1).

OBJECTIVES

- Develop a GIS Model representing the Metropolitan Information System (MIS);
- Identify, collect and transform graphical sketches of the city infrastructure and administrative precincts into digital format to use them for developing the MIS;
- Extract thematic information using cartographically correct planimetric reference as a base image;
- Compare the thematic information, pertinent to the urban infrastructure and administrative divides, developed from available sketch Maps and that from high resolution satellite Image dataset.

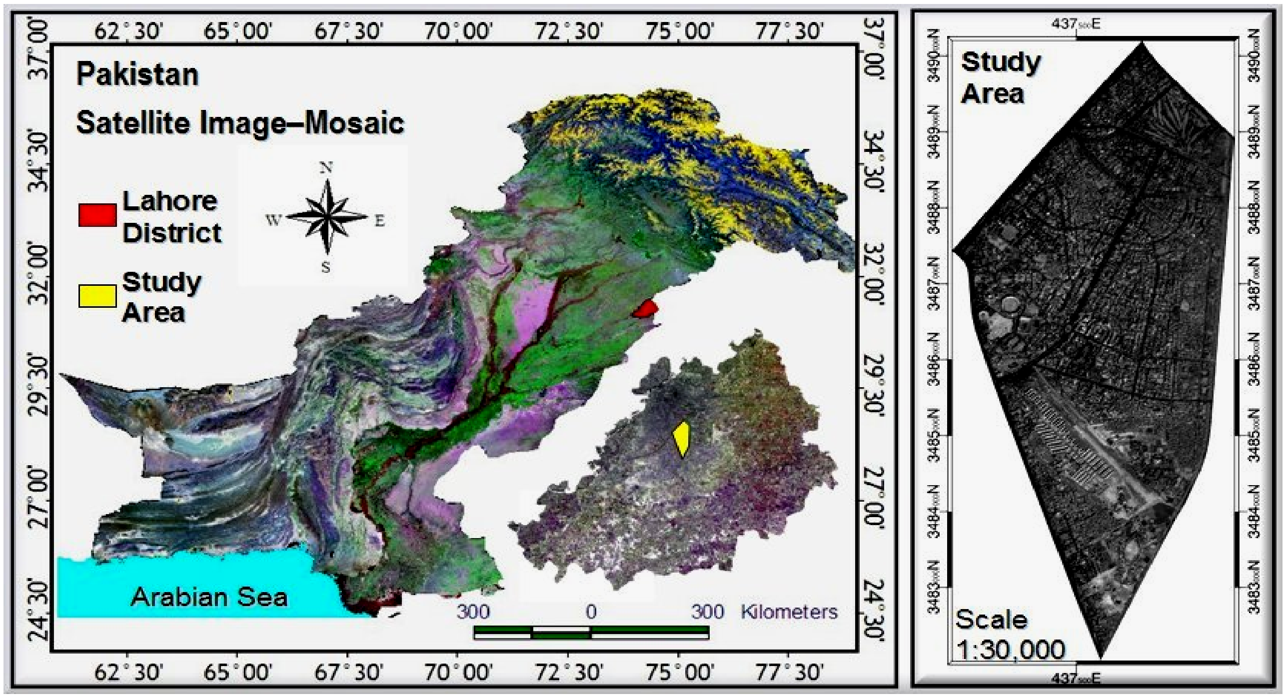

Figure 1: Plot of Study Area, with IKONOS (1m/pixel Resolution) Image of the AOI in Right Window.

The recent wave of interest in issues of good governance is at the helm of both administrative development and planning activities in Pakistan. Unless the distribution of Metropolitan service centers and the dissimilarities of its catchments are identified, remissions in good governance and service infrastructure remain difficult to overcome. GIS, RS, and related technologies continue to help scientists to study geospatial attributes of physical objects/ features and analyze their interactive characteristics.

Without the availability of a detailed digital context-sensitive geographic database of the Lahore City available with any institution to supplement the aforementioned issue of good governance, much less could be said about the urban expansion and its update.

Practically any information, with counterpart relationship to the geographic space, can be absorbed into the digital database as an aid to decision making. In the absence of conventional maps, very high resolution satellite images can be used to effectively monitor and implement changes in land use and urban expansion through detailed street level mapping. Towards citation of civic amenities, land parcelling, and commercial expansion, the resolution of data has surpassed incipient planning requirements. If such geographic sensitivity were to be available to the Lahore Metropolis office, the following information could be easily encompassed:

- Accessibility and shortest path routing to all service centers (e.g. for garbage collection and sanitation services);
- Siting buildings, streets, sidewalks, parking spaces and garbage disposal points with considerable accuracy of geographic location;
- Updated information on land parceling, real estate, and property surveys;
- Facilities management of Government administered schools, hospitals and other institutions;
- Expense verification on distribution and maintenance of green belts and horticultural sites;

- Zoning/ redistricting of service areas based on legal/ conforming uses and potential development of vacant lots; and

- Equitable distribution of time-limit emergency response facilities (Fire stations, police stations etc.).

And, of course, there can be other imaginative tie-ins to this spatial sensitivity, including inter-agency coordination and support to utilities distribution.

Problem Simplification

The procedure of developing the MIS has been split-up into the following steps:

- Develop a Common Platform for previously Mapped Information;

- Demarcate the Geographic citation of Civic Amenities, Land Parceling and Commercial areas;

- Layout the Distribution of Service Infrastructure vis-a-vis Administrative Divides;

- Develop Synergy between Conventional Alpha-Numeric Data (Post Offices, Police Stations, Mosques, Educational Institutions, Health Facilities, Fuel filling stations, Emergency response centers, Tubewells, Sewage, Sanitation, Green Belts, Encroachments, etc.) and Cartographically correct Geo-referencing;

- Provide a Standard Mapped Reference on Civic Infrastructure across all Working Scales of Planimetric Referencing; and

- Prepare a Digital Library of the Context-sensitive Metropolitan Information System.

Data Identification for Solving the Problem

- District Census Report (DCR) of Lahore City

- Lahore City Report

- Current and historic maps of Lahore, including:
    - District Map
    - Guide Map
    - Metropolis Map (Master Plan)

- Town Map

- Union Council Map

- Population Census Maps

- Maps from various service providing agencies (water, sewage, electricity, telephone, sui gas, etc.)

- Historic Maps to Monitor the City Expansion

- Satellite Image Datasets

Typical Thematic Layers for Developing MIS

- Base Map Theme: Administrative Boundaries(District, Municipal, Tehsil, Town, Union Council, Circle/ Maoza

- Linear and Curvilinear Themes: Roads, Access ways, Streets and Canal

- Infrastructure Layers: Water, Sewer, Power, Telephone, Sui Gas

- Location of Civic Facilities (Institutions, Health Centers, Mosques, Churches, Police Stations, Emergency Response Centers, Post Offices, Fuel Filling Stations, Important buildings, Markets, Banks, ATM Locations, Telephone Exchange, Grid Stations, Hotels & Restaurants, etc.)

- Environmental Themes: Well Sites, Dumpsters

- Planning Layer: Jurisdiction Precincts of Police Stations, Tax Zones, Post Code Extents, etc.

Most of the functions of city government involve planning and managing physical infrastructure. Estimates suggest that about 95% data collected and used by the local government has a spatial component that can be geocoded.

Administrative Boundaries – Hierarchical Setup (Population Census Plan, 1991)

- District (Called Lahore City District having same Precincts as of Administrative District)
- Town (Average population of 1.1m with Railway line/ Canal/ Road as Physical dividing features between any two adjacent Towns)
- Charge (Two or more Charges make one Union Council)
- Circle (Average Population 10,000 to 15,000 or in Exceptional Cases up to 20,000)
- Block (Consisting of 200 to 300 Households, one Household comprising 6 to 7 persons)

Development of a Model for MIS

As a representation or an abstraction of the observed reality, a model is always a simplification of the complexity of reality, which makes the reality more understandable and operational (Crowther & Echenique, 1972). Relying on the foregoing, a model of MIS has been conceived in order to place all the graphic, tabular and text information under one umbrella to visualize the civic entities and their inter-active aspects. The model is depictive of the sources, processes, relationships and usage of MIS for various user agencies and offers the facility of developing, editing, updating and browsing such information. A data model is an abstraction of the real world that employs a set of data objects that support map display, query, editing and analysis (Zeiler, 1999).

Digitization of Graphic Layouts and Image Datasets

As a first step towards satisfying the needs of MIS, a digitization procedure was started, followed by the precise geo-referencing of the graphic sketches of infrastructural and administrative layouts and satellite image datasets. The graphic sketches involved maps of Lahore City District Government (CDG), Water and Sanitation Authority (WASA), and Population Census Department (PSD). The satellite image dataset of the IKONOS Satellite at 1meter/pixel ground resolution, processed to the precision plus level was used as a base map. In addition to the IKONOS Imagery, Landsat datasets in panchromatic and multispectral modes for both Thematic Mapper (TM) and Enhance Thematic Mapper (ETM) were also used.

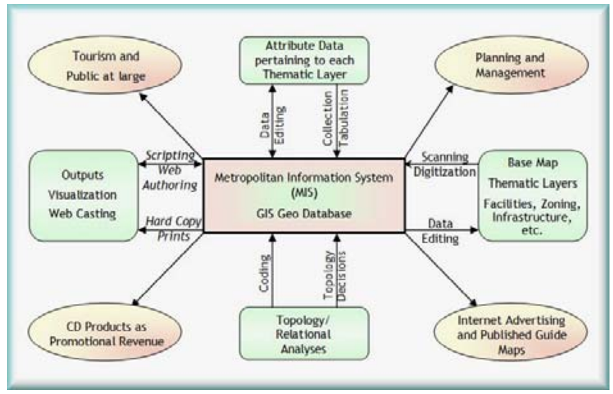

Figure 2: Layout of the MIS (Metropolitan Information System) Model.

The ortho-rectified Landsat images covered the whole Lahore district at 15m/pixel and 30m/pixel spatial resolutions in panchromatic and multispectral modes respectively. The aforementioned conventional maps do not have any geographic coordinate system and are being used by those agencies in the filed as a reference.

The delineation of boundaries on field-reference maps are therefore, not in conformance with the actual geographic locations of the administrative precincts. Hence, only the people who are already familiar with the area can use such graphic layouts. Moreover, every organization has its own field-use maps bearing no similarity and conformity with those used by the other agency. Resultantly, large differences in shapes and geographic locations of the administrative precincts have been observed, that further result into inability of using and sharing such data among agencies, responsible for providing civic amenities to the public at large, for effective surveying, planning and management purposes.

The precincts of Town, Union council (UC) and Census boundaries were digitized both on conventional sketches and the precisely geo-referenced satellite image datasets. The figures given blow are depictive of differences in delimitations, shapes and geographic locations.

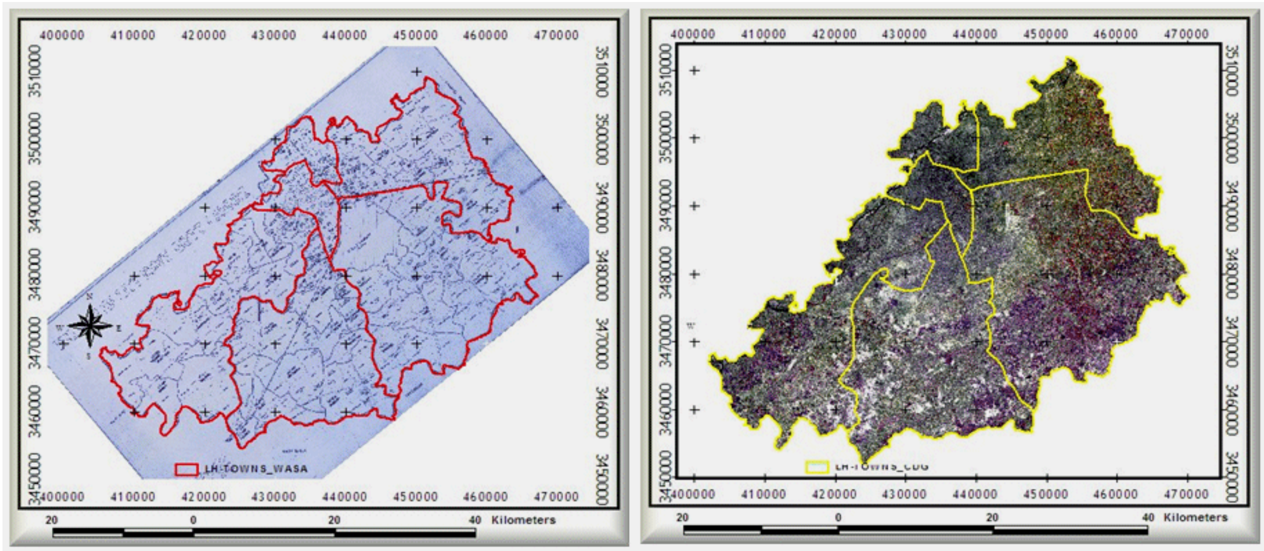

Figure 3: Town Boundaries Delineated on Sketch Map (Left) and Satellite Imagery (Right).

The union council boundaries were extracted from two different sources involving sketch maps of WASA and the high resolution satellite image of the Gulberg. On-screen digitization of the Union Councils 95, 97, 98 and 99 was carried out on the map of WASA, geo-referenced to UTM43 projection and WGS84 Datum. The same boundaries were digitized using satellite image as a reference. Both digital maps of the Union Councils with their respective reference map and digital high resolution image are shown below.

The features (Roads, Canal, Streets, Accessways) separating Towns and Union Councils from one another, were identified by the descriptive information provided by the Pakistan Census Department and the office of the City District Government.

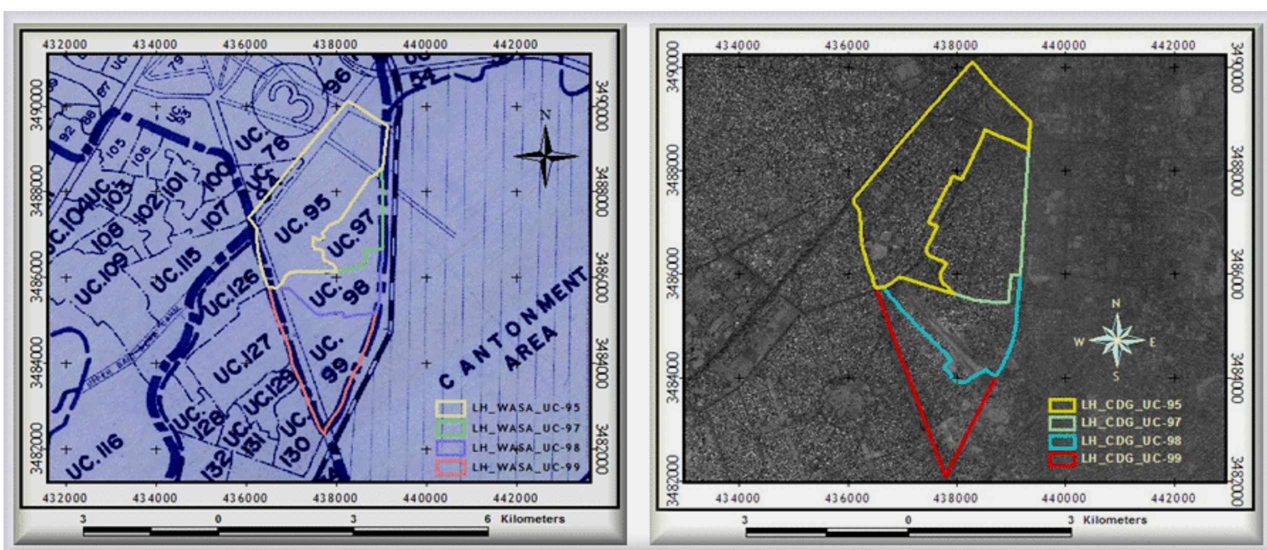

Figure 4: Union Council Boundaries Demarcated on Sketch Map (Left) and Satellite Imagery (Right).

The foregoing indicates that the norm of generating digital geospatial information pertaining to the actual geographic locations of metropolitan administrative precincts and civic facilities, along with the respective alphanumeric attribute data has not yet been established at organizational levels within the city administration. This is due to non-cognizance of modern geospatial techniques, where both alpha-numeric and graphic data can be combined on a common coordinate reference for making the geographic information both dynamic and sharable among the user agencies.

Once in digital format, it is always easier to update information after regular intervals of time. Moreover, uniform distribution of services can be planned and provided to the citizens provided context-sensitive information, abiding the similarity of geographic reference, regarding each civic entity is available. Such exercise facilitates the planning and development activities of all the responsible agencies of the Urban Government.

The shape, deviation, and variation in area extents of geographic boundaries of Towns and Union councils from their actual location is shown below.

All sketch maps of the Population Census Department (PSD) could not be geo-referenced due to enormous geometric irrelevance with the actual situation on ground. Since, the boundaries of the Census divides were indicated by road/ street names on the graphic layouts, hence the digitization of the Census Charges was accomplished on satellite image with the help of surrounding landmarks. Again, considerable geographic dissimilarities in cadastre precincts were observed on the sketch maps.

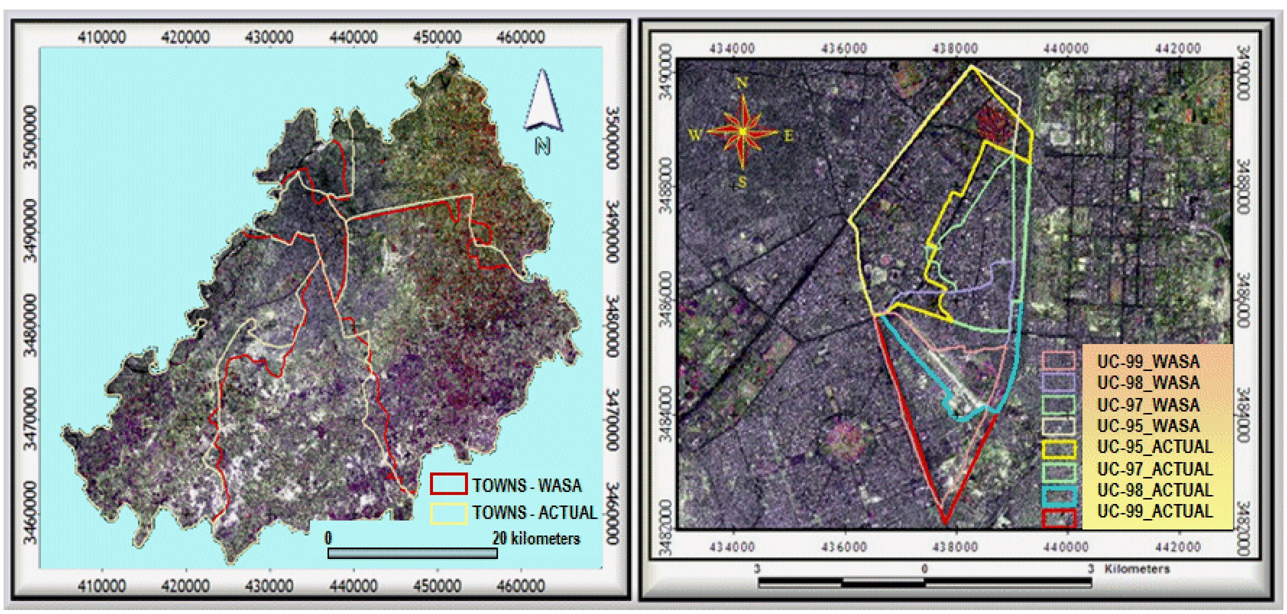

Figure 5: Difference Maps, Towns and Union Councils.

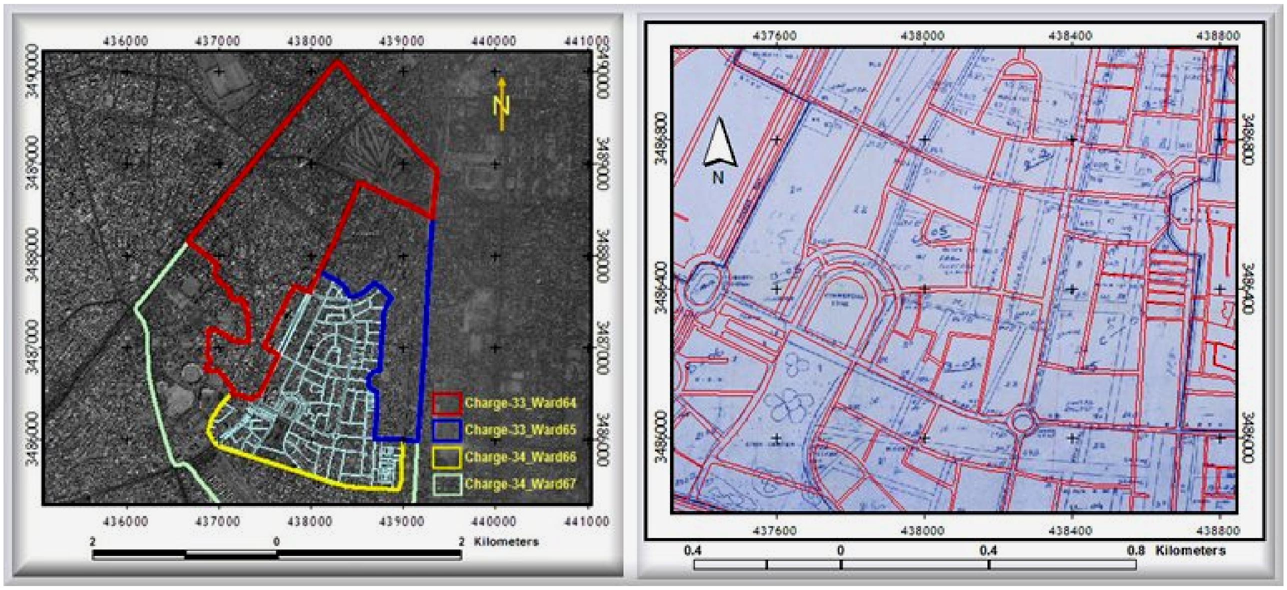

Figure 6: Left: Precincts of the Population Census Divides, Right: Geographic displacement in comparison to Actual Locations.

RESULTS AND DISCUSSION

The preceding description indeed represents a hectic effort in context of obtaining the existing conventional sketches of the civic layouts from respective organizations responsible for providing civic amenities to the public at large and then to exploit the available chaotic piles of data into useful, reliable, and sharable information. The results emphasize upon using accurately geo-referenced and very high-resolution satellite image datasets for digitization purpose, urban layouts for attributing and identification of administrative/ physical precincts on the earth's surface and actual ground survey/ truthing.

The digital high resolution imagery datasets provide amazing details of the earth surface but information extraction using computer-assisted classification techniques appear to be more complex (Carleer et al., 2005). The results presented therefore, rely only on digitization instead of image classification/segmentation.

Tables given below demonstrate the results of the study in the form of differences in cadastral precincts, while figures in methodology show the geometric shift with reference to actual locations.

Table 1: Difference between the Actual Extents of Town Boundaries and those digitized from the Sketch Map.

Sr. No.	Town	*Actual Precincts (sq.km)	**Digitized Precincts (sq.km)	Difference in area (sq.km)
1.	Ravi	070.85	056	14.85
2.	Shalamar	266.59	290	23.41
3.	Data Gang Buks	062.66	067	04.34
4.	Aziz Bhatti	543.94	517	26.94
5.	Nishter	433.64	421	12.64
6.	Iqbal	392.10	419	26.90

**Source: Sketch-Maps of City District Government and Satellite Image*

***Digitized from the Sketch-Maps of Water and Sanitation Authority*

Table 2: Difference between the Actual extents of Union Council Boundaries and those digitized from the Graphic Layouts.

Sr. No.	Union Council	*Actual Precincts (sq.km)	**Digitized Precincts (sq.km)	Difference in area (sq.km)
1.	UC-95: Alhamra	05.88	06.43	00.55
2.	UC-97: Gulberg	04.29	01.93	02.36
3.	UC-98: Makkah Colony	02.71	02.09	00.62
4.	UC-99: Naseer-Abad	02.52	03.81	01.29

**Source: Sketch-Maps of City District Government and Satellite Image*

***Digitized from the Sketch-Maps of Water and Sanitation Authority*

Table 3: Actual Area Extents of Population Census Divides extracted from very High resolution satellite Imagery Dataset.

Sr. No.	Gulberg Divides of the Population Census Organization	*Actual Extents (sq.km)	**Population	***Pop. Density
1.	Gulberg North, Charge-33, Ward 64 Circles: (1,2,3, 7)	03.78	25596	6771
2.	Gulberg East, Charge-33, Ward 65 Circles: (4, 5, 6, 8)	01.79	29199	16312
3.	Gulberg Central, Charge-34, Ward 66 Circles: (1, 3, 5)	02.93	25835	8117
4.	Gulberg New, Charge-34, Ward 67 Circles: (2, 4, 6)	04.37	27095	6200

**Source: Sketch-Maps and IKONOS Image*

***Both Male and Female*

****No. of Persons/ sqkm*

The difference indicated in the aforementioned tabular data is astounding. The mere reason has only been to rely solely on physical surveys while preparing sketches of administrative/ population precincts. This leads to make the maps non-sharable among the service providing organizations. The client / server architecture is desirable in an integrated urban information system, where parcel and land use objects are shared by many departments and agencies for varying purposes (Raza and Kainz, 2000).

Due to slack coordination among various organizational structures involving urban planning agencies, departments of the city local government, providers of the utilities, and other pertinent interests who conceive, execute and implement plans, geographic aspect of providing civic amenities to the urban community remains un-addressed. Consequently, geographic references/ maps developed by one agency for its own field-use do not match with those prepared by the other organization. No doubt, each agency has to fulfil its own responsibility (e.g., sewage map can not conform to the water supply map) but precisely generated infrastructural themes (road/ street network, precincts of administrative divides, drainage, and locality boundaries), geo-referenced on a mutually agreed-upon geographic coordinate system, may serve as a common base map that could certainly be used by each organization for locating, delineating and demarcating their respective facilities in the form of point (location), line and area features.

The MIS Model given in the methodology suggests a systematic way of analyzing problem of generating a context-sensitive urban inventory comprising both the geographic (maps) and alpha-numeric (attributes) elements in a combined form using state-of-the-art the geospatial techniques. All the inputs to, and outputs from, the MIS have been impounded in one model to facilitate preparation of such dynamic geographic databases for other areas of the urban environment to better plan, manage and implement the development policies. A well-conceived and implement-able model of Urban design acts as a guide for developers and designers; and possibly other agents, in planning and designing development, prepared by local authorities with the participation of landowners, developers, partnerships, business, and community organizations (Cowan, 2002).

Moreover, rapidly updating spatial syntax can be more nicely catered for in a digital database than its revision in conventional hardcopy prints already in use.

CONCLUSIONS

Rational development of MIS requires exploitation of GIS and Remote sensing techniques to address both the spatial and alpha-numeric aspects. A very accurately geo-referenced high resolution satellite dataset at 1meter/ pixel ground detail has been found very useful as a base map, not only for delineating the infrastructural features but also for appropriately re-positioning the urban features and cadastre boundaries, already developed by various administrative public and private sector agencies in the form of hardcopy graphic layouts for their own field-use, to the actual locations on the earth's surface.

Certainly, the datasets available with planning and management agencies are very rich both in the graphic and textual context, but bear inadequacies regarding non-conformity of graphic layouts with the actual landcover/ cadastral features and vaguely defined attribute data. The agencies involved in civic administration should take the initiative to transform the conventional data into digital geospatial information in order to cater the mounting needs of rapidly growing population.

The geographic information systems are the preferred paraphernalia to administer such a linkage for developing a Metropolitan Information System and provide a way in which the statistical results can be represented spatially on the map and spatial patterns can be recognized. Development of such systems will not only be useful for re-organizing the civic-information, but will also lead us to keep instep with the developed countries.

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