Development of Census-GIS Methodology in Pakistan

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Abstract

Census, which is generally conducted at decennial intervals in Pakistan, plays an essential role for collection of wide range of data. It is of prime importance for national planning as it is the main source for the study of various aspects of population, who are the beneficiaries/sufferers of any governmental policies. Manual methods of census conduction being cumbersome and erroneous, has become obsolete and outdated and is being increasingly replaced by automated methods, notably Census GIS. The objective of this paper is to present a model for the implementation of GIs for census enumeration, in order to overcome the inordinate delay in the last census in Pakistan, as census is the basis for streamlined and fool proof national, local and regional planning and disaster management.

Keywords: Census, data, GIS, Google Earth, modeling, Pakistan

Introduction

Census which plays an essential role for wide range of data collection at country level is of prime importance as it is the main source for study of various facets of population. Spatial distribution of population both rural and urban, temporal variations, social and economic characteristics ranging from housing to employment, migration, perspectives of ethnicity, epidemiology and health risk assessments, inequalities and poverty mapping, etc., are some of the aspects highlighted through census (Raymer, et al. 2009, Norman et al. 2008, Finney and Simpson 2008, Stillwell et al. 2008, Briggs et al. 2007, Norman and Bambra 2007, Huda et al. 2011, Shen 2005, Minot and Baulch 2005). In-fact, it is the most basic and essential source of data for any research and its implementation (Schroeder 2007).

The manual method of census enumeration, estimation and analysis is not only cumbersome and erroneous but quite obsolete and outdated. Implementation and continuous development of Census-GIS is the call of the post modern era without which handling of explosive, complex data seems well nigh impossible.
Maps are symbolic representations of real space and form the basis of spatial data collection, especially census data ((Martin 2000). The gap between reality and its symbolic representation has been shortened in recent years with digital multimedia information systems (Camara and Dias 2004). With reference to census data collection, different administrative units are followed in different countries e.g., in United Kingdom and United States the Enumeration Districts, in Canada Enumeration Areas, while in Japan the Basic Unit Blocks are the smallest census data collection units (Martin 2004, Côté 2005, Ragains 1995, IHARA 1998).

Geographic Information System (GIS) is one of the most in demand applications for the development of census activities (Martin 2002, 1998a, 1998b, Martin et al. 2001, Wu et al. 2008, Wang et al. 2001, Duke-Williams and Rees 1998). In the past several years, various developed as well as developing countries have been crucial in GIS application in census. (Schlossberg 2003, Mobbs 1998, Openshaw 1977, Xiru 2009, Tye 2009, Wall 2007, Verhoef and Grobbelaar 2005, Ralphs and Ang 2009, Prasad 2006, Owiti 2008, Laldaparsad 2007, Gregory and Ell 2005, Eze 2009). The growth of GIS through the 1990's led to a dramatic increase in the use of digital geographic data (Mokhele 2011).

GIS technology used in census becomes more sophisticated through open source high resolution satellite imageries of Google Earth including GPS built-in Trimple, Tablet and PDAs. The role of UN

for development support in terms of established GIS lab. with modern and latest software and equipments in developing countries has been one of the basic causes for promotion of Census GIS in the contemporary world. In addition, the UN Statistics Division succeeded in ensuring the NSOs of most developing countries with no-cost versions of commercial GIS software (UN 2000, 2004 2009). In Pakistan, UN based NGOs UNFPA with collaboration of Statistics Division, Government of Pakistan rendered massive support in terms of funds for the development of GIS based census. The present study has been designed from available and funded sources of Population Census Organization of Pakistan for the development of Census GIS. Census operation in Pakistan gained legal support in 1959, through a presidential ordinance, in which the definition of census along with other relevant matters were promulgated. The census not only involves coverage of area and population, but all topics of information regarding information on various social and economic parameters of the population (GoP 2010).

Census History in Pakistan

The first census launched in 1881 under the British rule, covered the areas now comprising Pakistan (GoP). The first census of independent Pakistan was conducted in 1951. The census tiers were Census District, Charges, Circles and Blocks. Each of the administrative districts with the exception of cities like Karachi, Lahore, Multan, Rawalpindi and Sargodha were subdivided into Census Districts. Each Tehsil/Taluka and in some areas Qanoongo Halqa (QH)/ Supervisory Tapadar Circle (STC), Patwar Circle (PC)/Tapedar Circle (TC) and Blocks that consisted of around 800 persons and a revenue estate or its part were formed.

In the 1961 census, further changes were made. Census Districts were arranged as
(a) Sub-Division or portions of a district
(b) Cities consisted of one or more Census Districts, and
(c) Big towns (above 0.1 million population) were considered as separate Census Districts.

At Charge level, the Divisions comprised Tehsil/Taluka or QH/STC, while urban areas were composed of Wards or parts of Wards. Census Circles were formed of small QH/STCs or PC/TC, while Census Blocks consisted of Mouza/Deh/Village or its part. For urban areas, Blocks has covered the specific ranges of housing units.

The third census which was conducted in 1972, envisaged more changes in methodology in comparison to the previous census. Major urban areas with population of 0.1 million or more were treated as one or more independent Census District. Census Charge is followed by each Tehsil/Taluka or QH/STC. In the urban areas they were treated as a Census District. A Census Charge was formed of Ward/ Union Committee or a part there of Medium size urban areas, constituted independent Charges, while the Census Circles were composed of QH/STC or their part. In the latter case, a group of PC/TC's combined to form a Census Circle. In urban areas (Census District or Charges) a Circle was formed of a Union Committee or its part. Small urban areas constituted independent Census Circles. A Census Circle was generally formed of about 1000 house holds. In the un-settled areas of NWFP (Tribal Area) a Census Circle was formed of a Union Council or its part. Census Blocks which was the smallest census area consisted of approximately 200-300 households or 1000-1500 population. In the rural setup a Mouza/Deh comprised of at least one Census Block.

In the third Census the need of maps in urban areas with large population concentrations was felt. It was realized that delimitation of census areas without maps was a difficult task. Three years prior to the conducting of Census, maps for field use were collected from the local councils i.e., Municipal Committees (MC)/ Town Committees (TC)/ Cantonment Boards. Some maps were collected from the Survey of Pakistan and Town Planning Departments. These maps were reviewed and where necessary, they were enlarged or reduced to suitable scales for the purpose of delimitation. Copies of tracings which were prepared were dispatched to the Local Councils for updating and for the purpose of Census and Blocks and Circles were marked. In the case of rural areas, taluka maps with boundaries of Census Charges and Circles marked on them were used.
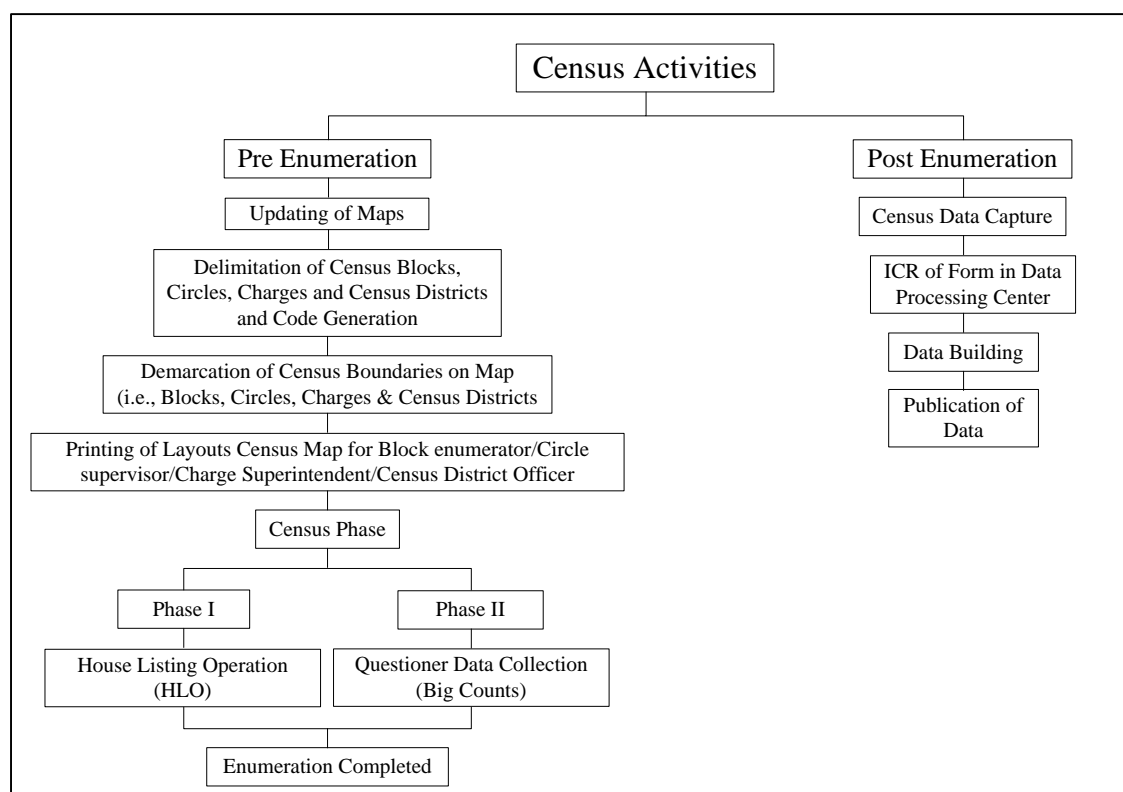
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                              Census Activities

              Pre Enumeration                      Post Enumeration

              Updating of Maps                     Census Data Capture

          Delimitation of Census Blocks,           ICR of Form in Data
          Circles, Charges and Census Districts     Processing Center
             and Code Generation
                                                       Data Building
          Demarcation of Census Boundaries on Map
          (i.e., Blocks, Circles, Charges & Census Districts)   Publication of
                                                          Data
       Printing of Layouts Census Map for Block enumerator/Circle
       supervisor/Charge Superintendent/Census District Officer

                    Census Phase

           Phase I                      Phase II

       House Listing Operation      Questioner Data Collection
            (HLO)                        (Big Counts)

                    Enumeration Completed
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Figure.1 *Ongoing Census Processes in Pakistan*

The four census tiers i.e. Census Districts, Charges, Circles and Blocks prevailed in the 1981 Census. Due to increase in the population of the administrative district and some undefined reasons each Sub-division of a district in Sindh, Punjab & NWFP were treated as Census Districts. In tribal areas and Balochistan, each administrative district remained as Census District. However, each Municipal Corporation (M.C)/Cantonments (Cantt.) having estimated population of 50,000 were created as separate Census Districts. Each Census Charge comprised of QH/STC Charge in Sindh, Punjab and settled areas of NWFP while in other areas each Tehsil/ Sub-Tehsil was formed as a Census Charge. Each urban Census District was delimited into two or more Charges. In addition, all other urban areas were treated as separate Census Charges. In the case of Census Circles, rural areas mostly PC/TC's were treated as Census Circles along with the un-settled areas of each Union Council of NWFP. In urban areas a Ward or a part of Ward or two or more Ward groups were treated as a Census Circle, on the basis of population. Each urban area (MC/TC/Cantt.) treated as Census Charge was further subdivided into two or more Circles. Census Blocks comprised of 200-300 households.
The five tiers of delimitation of census areas remained the same. But once again the Census District changed in the 1998 census. Each Cantonment, Municipal Corporation and each administrative district with the exception of the two i.e., (Karachi and Lahore) were treated as Census Districts. Similarly, in rural areas each QH/STC was treated as a Census Charge while in urban areas each PC/TC and MC and part of big cities with population ranging from 350,00 to 500,00 were treated as Census Charges. In rural areas each PC/TC were treated as Census Circle. In urban areas each (smaller town) committee was treated as a Circle. Generally, a group of 5 to 7 Blocks formed a Circle. A group of 150-200 households in rural areas and 175-225 households in urban areas were treated as Census Blocks.

Materials and Method

GIS applications can provide multi dimensional solution regarding census activities. In Pakistan, census activities designed can be according to the following steps i.e., geographical works (preparation of maps and delimitation of blocks) and data collection, updating of area list, in the case

of bifurcation of urban/rural administration recommendation based on population and housing data must be made, and Geo-coding of areas in accordance to the manual patterns (GoP, 2010). The present study has proposed Census GIS Model shown in Fig.1.

The proposed model anticipates need of the following supports:

1. All existing maps regarding census purpose must be available at micro-level i.e., layout maps, sketch maps, slum maps and maps of smallest revenue estates (Mouza/Deh) of administrative district.
2. A Google Earth satellite image for the base map while Google Earth Professional for image layout printing at A° size for field map.
3. Mapinfo Professional/ArcGIS, Global Mapper and Microsoft database packages for layering, database and conversion of format for ongoing activities.
4. A3 and Plotter for printing job and 42 inch Scanner for manual map scanning.
5. High speed internet connection (minimum 1mb bandwidth).
6. All supportive equipments for GIS and Data Processing Labs. (e.g. Computers, Window 7, Office Packages, SQL server, Networking, GPS etc).

Methodology

For application of the suggested model (Fig. 2) the applied methodology consists of several parts. Most of the stages are designed for laboratory work, while others are related to field data. After the setting of equipments in the GIS laboratory the prime concern is the organized running of the system. The general notion is that technological applications run automatically or under a single command. However, contrary to this, applications designed for any work varies. It is characterized not only by temporal variation, but spatial as well as environmental variations. In the post modern age, team work has been recognized as capable of producing the most exemplary results. The aim of the present study is the establishment of Census GIS with minimum expenditure and time lapse, where in every employed personnel will contribute their optimum efficiency. Fig.2 shows the placement of personnel with reference to the prime requirement of geographic data collection in the GIS Laboratory.

Fig.3 shows classification of works in the GIS Laboratory. This model consists of three major desks on the basis of experience and expertise. Significance of this model is that requirement of geographic data for census have been classified where low experience perform their work simple vectorization e.g., roads, rivers, canals, drainage, shape of rural settlements, etc., while highly experienced personnel who have stronger commands in manual cartographic and geographic work but with lesser experience in computer applications will do the job, e.g., demarcation of Census Blocks in terms of rural/urban, labeling of road networks and other line data, etc. The concept of layer development will be accomplished by personnel who have the knowledge of GIS software applications like Mapinfo/ArcGIS etc. GIS analysts perform the final task of development of Census GIS. Fig. 4 shows channelized mechanism in GIS Lab. where all the different stages from initiation to completion of census work is performed.
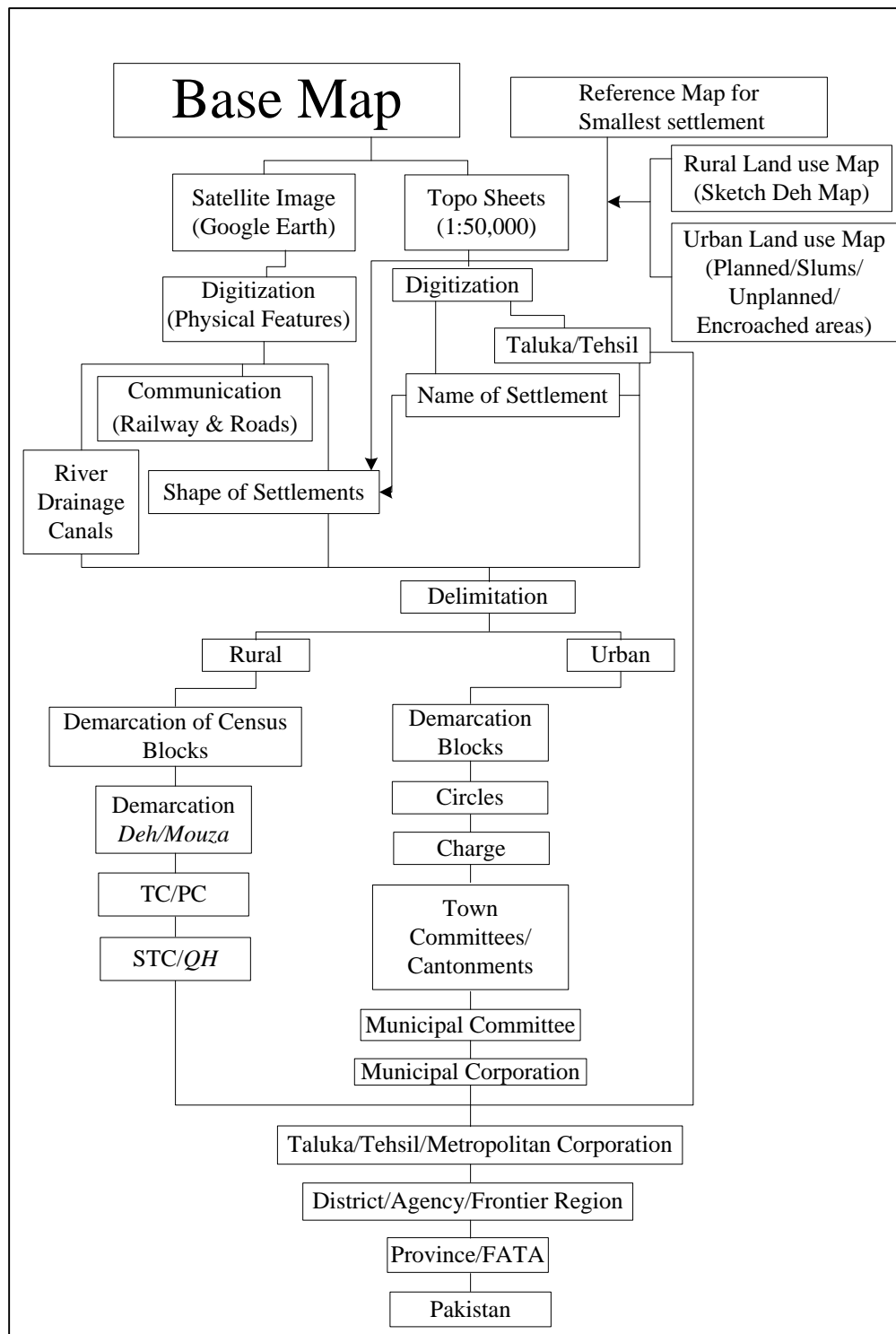
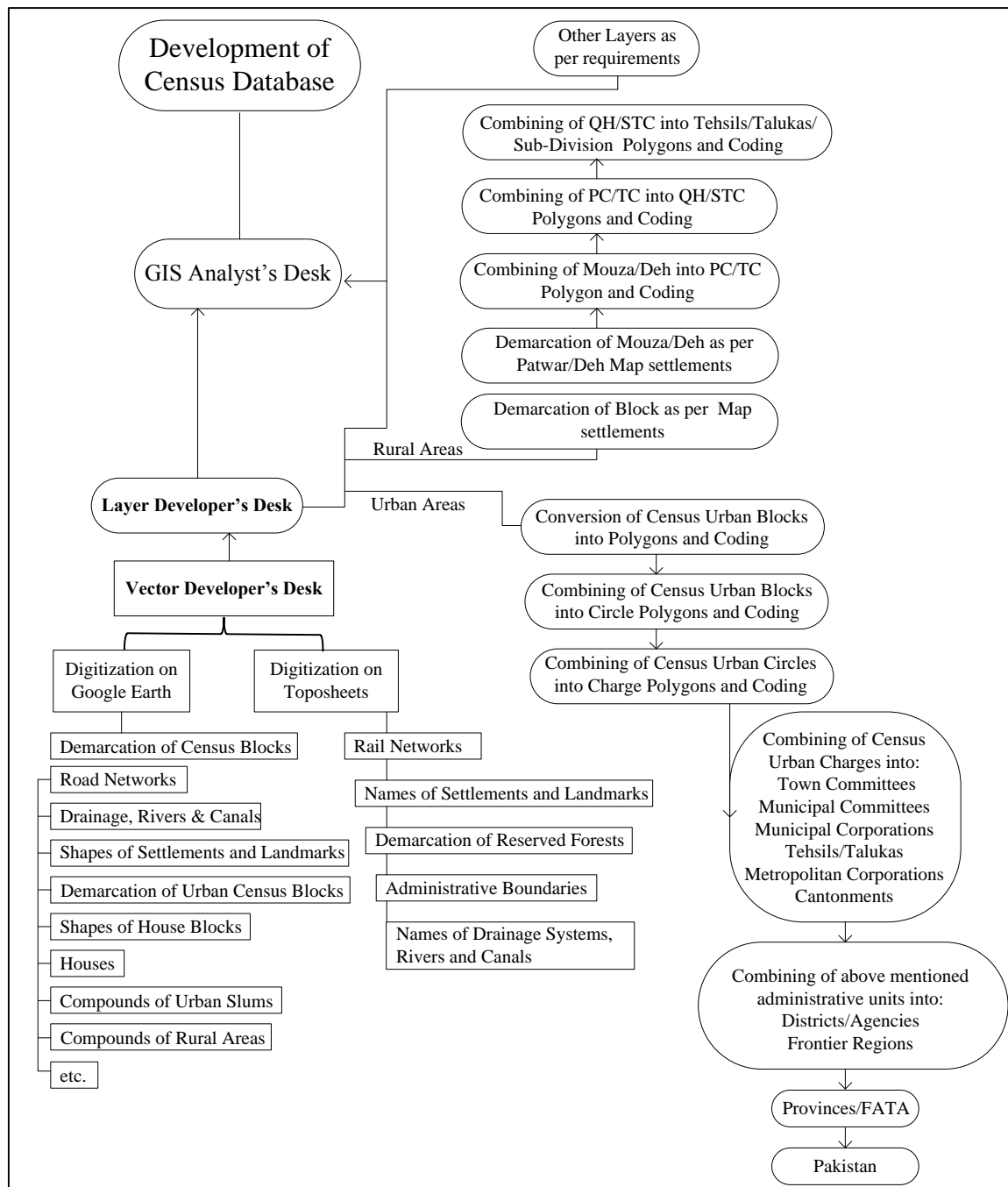**Figure.2**: *Proposed Model for the Development of Census GIS*

Figure.3. *Desks in GIS Laboratory.*

Mechanism of Works Distribution in C-GIS Lab

Stage I —— **Stage II**

Demarcation of Census Blocks on Satellite Images (Google Earth)

Verification of Blocks

Formation of Circles

Formation of Charges

Final Layers (Blocks, Circles & Charges)

Stage III

Preparation of Circle Image Layout for Print at Block Level

Digitization of Transportation Network (Google Earth)

Labeling of Streets, Roads, Highways, Railway lines

Final Layers of Transportation for Census Activity

Field Updating

Collection of Point Data and incorporation on GIS database

Digitization of Canals, Rivers and Drainage Pattern (Google Earth)

Labeling of Canals and Drainage Systems

Final Layers of Canals & Drainage for Census Activity

Modification in Census Boundaries, Demarcation of Mohallas and Road Network on GIS database

Digitization of Shape of Settlements (Google Earth)

Labeling of Settlements from Manual Deh/Town Maps & Sketches

Demarcation of Deh/Mouza

Digitization of Toposheets for extraction of Settlements Name and Administrative Boundaries from SoP.

Stage IV

Preparation of Vector Map Layout for:
Census District Officer
Charge Superintendent
Circle Supervisor and Block Enumerator

Stage V

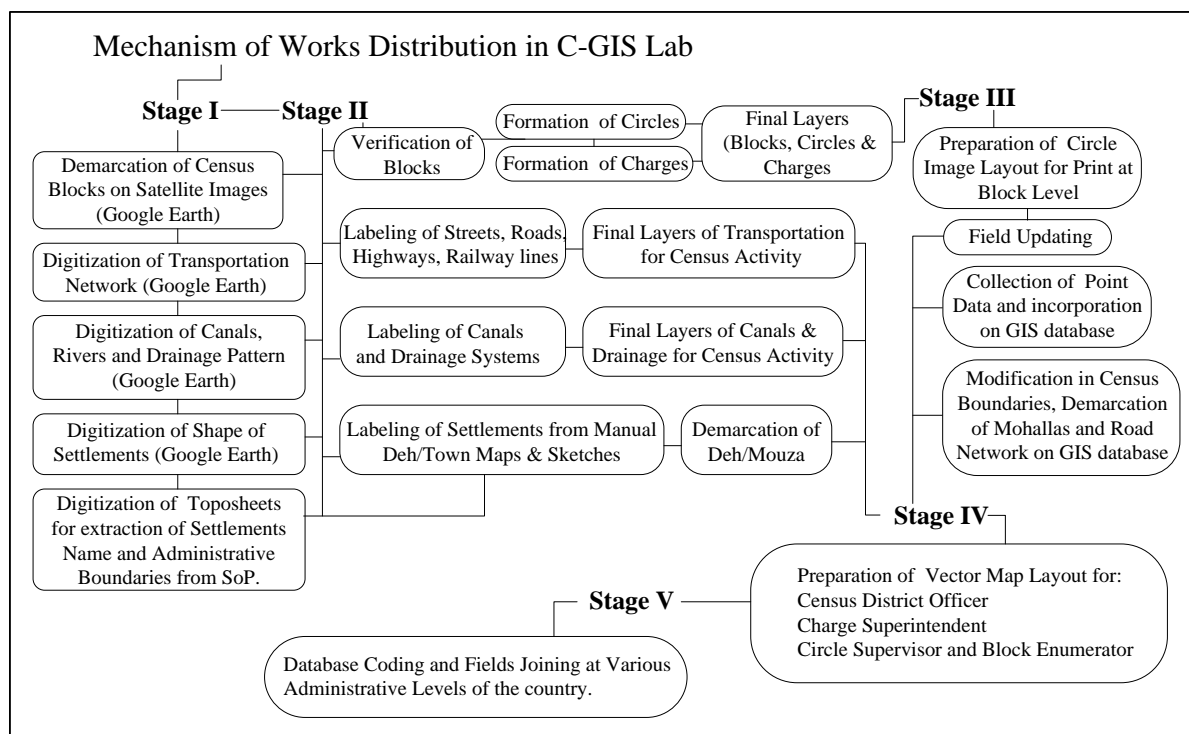Database Coding and Fields Joining at Various Administrative Levels of the country.

Figure.4. *Channelization of work in GIS Laboratory*

Results and Discussion

GIS is a convenient method for collection of census data and providing the underlying geographical framework. It serves as a fundamental resource for social, demographic, economic applications as well as for regional planning (Barr 2007, Cai et al. 2006, Martin et al. 2002, Harris & Longley 2000). However, there are some challenges faced during geographic data collection regarding Census GIS which are as follows.

- Google Earth images do not cover entire Pakistan at high resolution.
- Mosaics of images show geo-reference/ rectification errors.
- Images pertain to various dates, some being recent while others couple of years old which causes digitization problems.
- There is temporal variation of settlements over the same space as a result of which administrative and census boundaries keep changing in each census.

These problems lead to escalation in cost of census GIS in developing countries. However, enhancement of Google Earth images along with maintaining intact boundaries of census and administrative areas can help control/reduce the cost incurred.

In the case of settlement expansions, areas of new cities/towns maybe demarcated. With the help of GIS techniques trend analysis and comparative studies can be made, which will prove beneficial for regional, urban, environmental, demographic, administrative, disaster planning, etc.

Fig.5. reveals the overall Census GIS activities suggested. The model covers both manual as well as modernized census conduction in Pakistan. In the post enumeration phase of census activities editing of Intelligent Character Recognition (ICR) census data is an essential stage in which the editing program should be developed by personnel in accordance to edit specification. Edit packages which have been developed for particular geographical socio-economic and demographic environments are also available.

Prior to the actual editing operation, the editing package/program must be tested. For this purpose dummy data file can be created or the data collected through pretest/pilot census may be used to check all steps of editing. Data from ICR census form is converted into single record for each person within a household and households within a block. Each block contains 9 digit geo identification numbers. The computer assumes an important role in cleaning, editing and imputing of

missing values, checking consistency, completeness and accuracy of data. The success in achieving these objectives depends on the editing program/package used for editing of data and the quality of manpower deployed for this purpose. Edit specification are the basic tool for computer editing which should be developed by the subject specialist in collaboration with the computer personnel. Edit instructions should describe the action to be taken on each data item. The instruction should be clear, concise and unambiguous which are clearly understandable for the program. Sorting of data prior to the actual edit, a sort program is run to arrange the records in sequence by blocks and households within blocks.
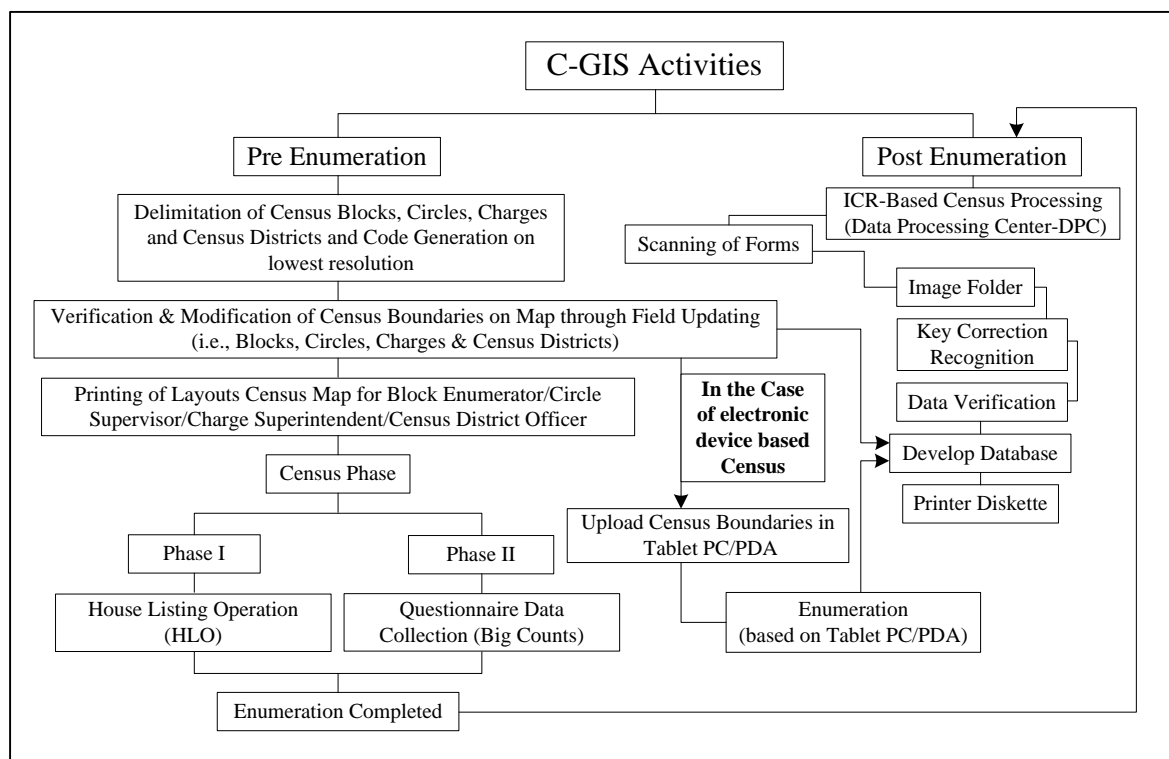
Figure.5 *Census-GIS activities*

A control edits checks the duplication and missing records and produces a summary total. After these operations, a master file is created. The edit program is executed to edit/correct invalid data of all census forms according to their edit specification. Edit statistics for each data item is generated. In case, numbers of corrections for any item are more than acceptable limit, data file will be reviewed. After cleaning the data files of a district, common information of short and sample forms will be merged to give 100% population and housing information. The first step of computer editing will be the range edit which checks each response to determine whether or not they are valid codes. The range edit also includes a check for blanks/omissions. This edit should produce error listing and edit diary. The consistency edit checks whether a predetermined relationship exists between two or more data items within a record as well as between records. This edit check will also produce error listing and edit diary. The edit program is used to incorporate the corrections in the file. All updated records are reprocessed through the edit program till the data are cleaned. Raising factors will be developed at district level separately for urban, rural and by sex and age groups for preparation of sample tables. Imputation is the process of assigning reasonable entries in the data field with missing or invalid entries. For this purpose the following methods are commonly used. Hot Deck method is the method where by missing/invalid entries are imputed using a valid response from the last record in the file with similar characteristics. As the data is processed the stored values are constantly updated by valid response. Cold Deck method provides, help to the missing/ invalid entries which are imputed using the fixed values from the auxiliary data e.g., data of previous census or pilot census. Frequency Distribution technique provides support to the missing or invalid entries which are imputed on a

proportional basis, from a distribution of valid responses of the current census/survey. The last step in ICR is quality control of computer edits. The purpose of the quality control is to prevent distortion, duplication and a loss of data. Excess editing should be avoided. A diary should be prepared to show the results of computer editing. This diary should contain the number of errors, types of errors and percentage of errors by area. These diaries are used to document the results of an edit and information about changes made in the data.

Finally, Fig.6 shows choice of topics to be covered in a census which depends on national needs and which is tremendously increasing, while census has its own limits. Thus, a balance has to be maintained in what census can produce with desired accuracy against the demands of most of data users (GoP 2010).
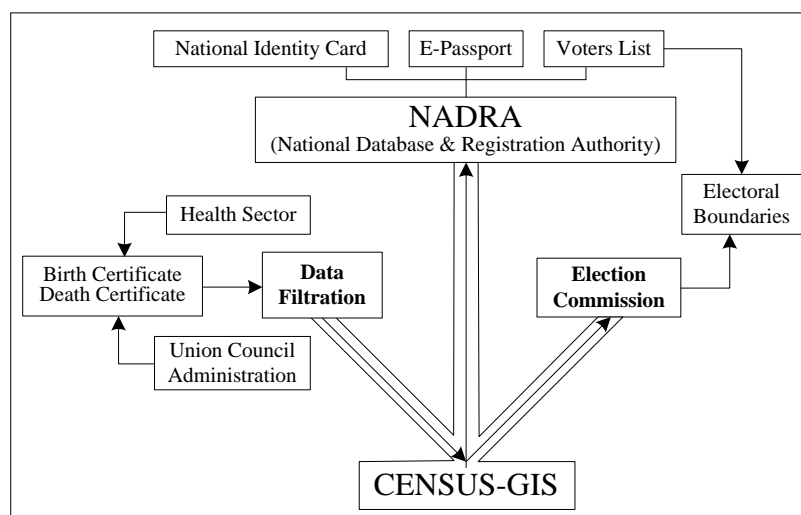

Figure 6. *Collaboration with other departments*

Conclusion

In developing countries like Pakistan, GIS is a new technology, the implementation and utilization of which has increasingly enhanced working of government organizations, especially in terms of data base development. This technology growth is promising not only in all sectors of planning at governmental but nongovernmental level as well. The Statistics Division of the United Nations has played a very constructive role in promoting the development of GIS based census technology especially with reference to software equipments and manpower training. Qualitative as well as quantitative benefits of handheld devices (Tablet, Mobiles etc.) have been proved in the field in many countries (e.g. Australia, Canada, Brazil, Malaysia, New Zealand, etc.) and there are various options available for selecting those devices. Clear identification of objective is necessary for selection of best devices.

Census GIS not only provides immense help in regional planning, but its efficacy can be proved in the case of disaster management as well. There is great need for detailed research in applications of GIS as well as other GIS technologies in census data in order to have comprehensive and fully informed policies and decision making.

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