Assessment of GIS for the Population and Housing Census in Iraq

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Economic and Social Commission for Western Asia

Assessment of GIS for the Population and Housing Census in Iraq

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Key messages

- *Geospatial information technologies have greatly improved and become more accessible and affordable, rendering hand-drawn maps less used than of the past.*

- *In the 2010 census round and even more in this current 2020 round, countries adopted these new technologies with varying levels of success.*

- *With the right mix of resources and skills, countries can greatly improve their map production and field monitoring to collect precise and quality population and housing data for the census, and the building of a well-structured geographic database.*

- *For the successful outcome of the mapping exercise, Iraq Iraq's Central Organization for Statistics and Information Technology (COSIT) should build a strong team skilled in imagery and remote sensing and equipped with the appropriate material to perform the imagery processing tasks.*

- *Capacity building in imagery processing and an external technical assistance need to be considered.*

- *For its upcoming census, COSIT plans to adopt for the mapping activities an integrated electronic system approach composed of Geographic Information System tools (GIS), and tablets for enumeration areas (EA) boundaries updating and numbering of buildings.*

- *The integration of Computer Assisted Personal Interviewing (CAPI) with GIS is not an easy task; it requires specific skills and capacities for this demanding work, so that few National Statistical Offices have them all in-house.*

Executive summary

Geospatial information methodologies and technologies have been adopted by National Statistical Organizations (NSOs), including in many developing countries, with the recognition that the appropriate use and application of these technologies is beneficial to efficiency in the preparatory, enumeration, processing and dissemination phases of the population and housing census (PHC), and ultimately to its overall quality. Today, virtually every NSO uses a geographic information system (GIS) to create digital maps, create and maintain databases, disseminate geostatistical products, and provide a wide range of services. Building a statistical-geospatial infrastructure in support of censuses and statistical activities is particularly recognized as an enabler for facilitating data sharing and improving the availability and access of country information in support of evidence-based decision making and sustainable development.

In fact, the United Nations has recommended that countries should build, develop, and strengthen their geospatial information infrastructures in support of census and statistical activities and recognize that the adoption of a geographic-based approach with full integration of statistical and geospatial information offers an opportunity for countries to proceed with the modernization of their national statistical systems and official statistics,[1] and build their capacities to be able to fulfil the 2030 Sustainable Development Agenda challenges.

It is under this mandate that the Central Organization for Statistics and Information Technology (COSIT) in Iraq aims to use innovative geospatial information technologies in support of the country's upcoming census and to ensure their adoption and implementation in accordance with United Nations recommendations, taking into account its own specific national circumstances. In this regard, the United Nations Economic and Social Commission for Western Asia (ESCWA) has commissioned this assessment report that identifies the scope and the gaps of the existing geospatial infrastructure within the NSO in Iraq, with operational guidelines on the use of the geospatial information technologies at every stage of the census, and on identifying the resources and capacities to assure their implementation and monitoring.

1 In-depth review of developing geospatial information services based on official statistics, Note by the United Kingdom Office for National Statistics, CES, 2016, ECE/CES/2016/7.

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Acronyms

CAPI	Computer Assisted Personal Interviewing
COSIT	Central Organization of Statistics and Information Technology
DESA	Department of Economic and Social Affairs
ESA	European Space Agency
ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
ISO/TC211	The International Organization for Standardization (ISO) Technical Committee 211 Geographic information/Geomatics
NMA	National Mapping Agency/Authority
NSDI	National Spatial Data Infrastructure
NSO	National Statistical Office (Organization)
OGC	Open Geospatial Consortium
PES	Post Enumeration Survey
SDGs	Sustainable Development Goals
UN-HABITAT	United Nations Human Settlement Programme
UNFPA	United Nations Population Fund
UNITAR	The United Nations Institute for Training and Research
UNSD	United Nations Statistics Division
WGS84	World Geodetic System 1984
WHO	World Hydrography Organization

Introduction

The Central Organization of Statistics and Information Technology of Iraq (COSIT) plans to conduct its upcoming census in compliance with Principles and Recommendations for Population and Housing Censuses (United Nations publication, 2017) where countries are encouraged to keep abreast of the technological developments made since the previous 2010 round, especially concerning the use of the geographic information system (GIS) and other geospatial information technologies such as the global positioning system (GPS), satellite/aerial imagery and spatial analysis in census operations, from the preparatory stage to the dissemination of census results[2] and beyond.

Following the strategic decision by COSIT to use GIS-based mapping and the computer assisted personal interviewing (CAPI) method for data collection with handheld devices, ideally equipped with the global navigation satellite system (GNSS) or GPS, certain proposed activities need to be conducted for the development of a digital census mapping programme with the use of geospatial technologies at the three stages of the census. Specific guidelines for the demarcation of enumeration areas (EAs) and the establishment of an EA-based geographic database will be outlined, in addition to the technical and human resources needed to conduct a full digital census mapping exercise.

This study commissioned by ESCWA reports on the geospatial infrastructure situation through an inventory of the existing geospatial data and mapping, hardware/software and skilled manpower available in COSIT; it evaluates the challenges and recommends the best way to use the existing resources; it identifies the new resources that need to be acquired and produced; and it determines the best technical solutions to conduct the upcoming GIS-based census mapping operations. More specifically, the report includes guidelines on the EA delineation process, building a geographic database, the procedures to conduct a pilot GIS mapping exercise and recommendations on the resources needed to accomplish a successful full GIS-based census mapping exercise.

2 As stated in Principles and Recommendations for Population and Housing Censuses, Revision 3 (United Nations publication, 2017). Available at https://unstats.un.org/unsd/demographic-social/Standards-and-Methods/files/Principles_and_Recommendations/Population-and-Housing-Censuses/Series_M67rev3-E.pdf.

1. Inventory of the existing GIS/mapping situation and needs assessment

Based on good practices in line with United Nations principles and recommendations, a GIS-based census mapping program should be developed at an early stage of census planning to allow sufficient time to produce full national coverage of EA maps well before the census date, given that this is a time-bound operation; the critical date is when all enumeration-related maps and map services must be made available for census field enumeration procedures.

At the institutional level, the technical and organizational and institutional tasks to be carried out are identified through the planning process. Our diagnostic of the institutional situation reveals that there is no single national authority for geospatial information in Iraq, as some governmental and service organizations have their own GIS departments that assume responsibilities related to the tasks of those institutions, which is the case with the Iraqi Central Statistical Organization. While the Iraq COSIT does mapping work to cater to its own needs, it also participates in supporting the field work of the Ministry of Planning and assisting researchers from outside the institution and graduate students in the field of geographic information systems. This mission is consolidated by the adoption by the Council of Ministers of Iraq on 21 January 2021, of the law on statistics and geospatial information systems,[3] leading to the creation of an authority for statistics and geospatial information, resulting in improved coordination and integration of statistical and geospatial information.

At the technical level, for a GIS-based census mapping program available geographic and technological resources must be evaluated together with the critical design issues that determine the nature of the census GIS, focusing on its core geospatial database and the range of applications that it will support. Of particular importance is the data inventory of existing maps and other geographic data sources, and the data conversion and integration processes which all depend on a well-designed institutional environment and a well-planned operational strategy.[4]

A comprehensive inventory of all the existing maps and imagery in the country, in analogue or digital formats, covering the whole country with different scales and at various levels is needed to identify those which are suitable to meet the needs of enumeration demarcation. This includes small-scale rural and urban base maps covering the whole country topographic maps; large-scale base maps at town and city levels showing land parcels, details about

3 Available at http://cabinet.iq/ArticleShow.aspx?ID=10997.

4 Details in the Handbook on Geospatial Infrastructure in Support of Census Activities (United Nations publication 2009). DESA – Statistical Division. Available at https://unstats.un.org/unsd/demographic/standmeth/handbooks/series_f103en.pdf.

important physical features such as streets and roads, parks, water features, city buildings and important landmarks (city and cadastral maps); maps of administrative units at all levels of civil divisions; thematic maps showing population distribution for previous census dates, or any features that may be useful for census mapping; and even sketch maps; relevant high-resolution satellite images and digital aerial photos, and GPS data collection.[5]

A possible outcome of the inventory may be to show that the existing maps do not fully provide all the data needed, requiring some additional traditional fieldwork or additional searches in various data sources to be carried out. The desired final outcome would be to have a mapping/geospatial infrastructure available to carry out the census mapping operations.

For this purpose, the consultant prepared a questionnaire (annex 1) which was completed by the COSIT Centre for GIS, in the absence of the national mapping agency as the main provider of geospatial data for the census and even for other governmental departments. Additional information was gleaned from the responses provided by COSIT to an ESCWA questionnaire (annex 2) as well as online interviews with COSIT GIS and information technology (IT) directors.

Based on the analysis of the responses and the consultations, the inventory of the current geospatial data in Iraq shows that: (i) there are no updated base maps, and the existing maps at COSIT are mainly administrative maps (at scale 1:250.000, date 2002, source: General Survey Authority), showing administrative unit boundaries of civil divisions (Iraq has 15 provinces, plus three provinces in Kurdistan); (ii) instead, COSIT has 2018-2019 WorldView[6] satellite imagery provided by UN-HABITAT covering 270,000 km^2, most of Iraqi urban and rural areas but without the desert region. While the satellite imagery dated 2018-2019 is not old, it is nevertheless not recent enough for a census, as it must be less than a year old; (iii) the datum for the national geodetic/spatial reference system is based on WGS84 UTM Zone 37, 38 and 39; (iv) the GIS software available are 1 ArcGIS Enterprise Advance, 1 ArcGIS Image Server and 100 ArcGIS Desktop Advance with Extensions, with a central geographic database (a multilayer geodatabase, but not at EA level); (v) with regard to the infrastructure/equipment, COSIT has a GIS centre with around 40 staff and hardware including desktops, laptops, printers, plotters, scanners, rack (for full list of existing hardware and software, annex 3). Although COSIT does not possess GPS units, its staff do know how to use GPS in the field.

The inventory shows, in particular, that GIS and mapping capacities in COSIT are quite significant, meaning they have the capacity to provide the needed support to COSIT at every stage of the census operations, as long as GIS centre staff are trained and up to date with recent technological developments. This means COSIT has to develop and strengthen its GIS and IT capacities for the use of geospatial information technologies during the census mapping process at all stages. As the use of geospatial technologies may be costly in the initial stages, they will produce a return on investment if they are used not only for the census, but also beyond that event.

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5 GIS and the 2020 Census: Modernizing Official Statistics, 2019, Esri Press. Available at https://www.amazon.com/GIS-2020-Census-Modernizing-Statistics/dp/1589485041.

6 WorldView-2, a commercial Earth observation satellite owned by DigitalGlobe, provides commercially available panchromatic imagery of 0.46 m (18 in) resolution, and eight-band multispectral imagery with 1.84 m (72 in) resolution.

Nevertheless, resources will be needed to acquire handheld devices (thousands of tablets with in-built GPS/GNSS receivers), communication equipment and systems (such as virtual proxy networks (VPN) to ensure efficiency, security and confidentiality of data acquisition and transmission), and probably the outsourcing of the development of apps and integration of CAPI and GIS maps. Since recent satellite imagery is desperately needed to form the basis of the delineation of EAs, and as backdrops on the handheld devices, resources should be allocated for their acquisition as well for their processing.

2. Supporting and implementing geospatial activities for the pre-enumeration phase

The preparatory stage is crucial, as the staff at COSIT need not only to prepare for the pre-enumeration phase of the census, but also to think and plan about all the technology and other requirements for the enumeration and post-enumeration phases. In the following section, we define the activities needed for the pre-enumeration phase, and the technical solution that will help to carry out all the census activities.

A. Census geography and mapping infrastructure

Census geography refers to how the country is geographically divided prior to the actual census enumeration in order to facilitate field operations, data processing and analysis, and ultimately reporting and disseminating census results. One of the early key actions in the development of a census mapping program is to determine the geographical units for census enumeration, as the definition of "geography on which the census is collected will determine the geography on which the census data can be disseminated".[7]

The inventory of the sources of geographic data helps determine the way we construct the census enumeration areas for data collection (census blocks, buildings and dwellings), that would constitute the basic features of the census GIS database. In the case of Iraq, with the absence of base maps, which generally constitute the main sources of data for the delineation of enumeration areas, emerging data sources such as satellite imagery and other (aerial and drone) imagery should be used to support the delineation of enumeration areas process.

To this end, we need to start to review and update the existing coding scheme to have a geocoding system which constitutes the reference giving all the census units (census blocks/enumeration areas, buildings/dwellings) their geographic dimension, in providing a unique identifier (code) which creates a link between GIS boundaries and tabular census data. To sustain this link, the geocoding system is generally designed to be sufficiently flexible and well-structured to incorporate changes to and divisions of current new and future administrative boundaries. Nested codes are considered best practice and should be respected where possible.

Proposed coding scheme

The existing administrative hierarchy needs to be reviewed to create an accurate geographic frame, where EAs (with buildings and dwellings) form the smallest geographic units of the geographic frame and fall within 'Mahalla', 'Annahia', 'Qadhaa' and 'Mouhafadha', to ensure that their

7 As stated in Principles and Recommendations for Population and Housing Censuses.

boundaries are as accurate as possible. The development of a geographic frame should encompass the foundational elements related to the smallest statistical units, but also incorporate other reference information, such as topography, elevation, land parcels, transport networks, etc. Only once the geographic frame has been created can the re-demarcation and updating of EA boundaries begin (next section). In this regard, a review of the coding system has been discussed with the COSIT team, and there is agreement to consider the following coding scheme as is indicated in figure 2.

Note that an agreement was reached to add to the initial coding scheme 1 digit for Urban ('Mahalla')/Rural village ('Qariya'), and two digits for 'Building' to codify any left-over 'Building'. Figure 2.

With regard to GIS software used at the global level, free/open-source software (FOSS) such as QGIS, PostgreSQL or GRASS, with some applications for surveys, is generating increasing interest, but has not yet been mainstreamed into the census GIS process.

Figure 1. Type of administrative hierarchy/coding scheme designed by COSIT

المحافظة	رمز المحافظة	القضاء	رمز القضاء	الناحية	رمز الناحية	المحلة	رمز المحلة	اسم المعاون	رمز المعاون	حذف المهمة
بابل	24	الحلة	1	ابي غرق	3	121	121	fieldworker	4007	حذف
بابل	24	الحلة	1	ابي غرق	3	103	103	fieldworker	4007	حذف
بابل	24	الحلة	1	ابي غرق	3	107	107	w	5007	حذف
بابل	24	الحلة	1	ابي غرق	3	105	105	...Mohammed	5009	حذف

Source: Designed by COSIT.

Coding Scheme (updated and agreed):

Figure 2. Type of administrative hierarchy/coding scheme updated by the Consultant and agreed by COSIT

Note: 'Mouhafidha' 'Qadhaa' 'Annahia' U/R 'Mahalla'/'Qariya' EA/Block Building (3+2 for left over buildings).

For the CAPI method used in combination with GIS mapping functionalities, there is Survey Solutions, a free software for data collection and survey management developed by the World Bank. Survey Solutions has powerful CAPI capabilities, guiding interviewers to the point of interview offline using high resolution satellite images and built-in GPS receivers, but still with limited mapping and GIS functionalities (We should not expect that an open-source software like Survey Solutions dedicated primarily to surveys and questionnaire forms can offer advanced GIS or mapping capabilities).

A quick survey of commercial software shows that the most used GIS software is ArcGIS, developed by Esri, which, with its additional apps to be used for CAPI-based field data collection, such as Survey123 and Collector, constitutes an integrated suite for census field operations. Aside from marketing, this lack of use of free open source software may be largely due to the poor technical support and reliable documentation, in addition to an inconsistent support community when compared to the Esri products and related significant support and user communities. Moreover, other commercial GIS and associated software such as MapInfo or AutoCAD are usually used by countries in conjunction with Esri products.

B. Enumeration areas design/EA maps

The primary aim of a census mapping exercise is to facilitate the preparation and production of census blocks/enumeration areas maps that would be used for the location and enumeration of households at a national level during the data collection phase of the Population and Housing Census. With the use of contemporary technologies, the approach relates to the development of a census GIS infrastructure for map production and the incorporation and use of available data (e.g., base maps, road and water bodies data sets) so that EA boundaries are clearly delineated and correspond to physical ground features to ensure that there are no omissions or duplications of territory coverage.

Based on the inventory, COSIT has a geodatabase composed of multiple geographic data layers, but not at the EA level, which means COSIT needs to build its database at the EA/buildings level, where EAs covers the whole country, including urban and rural settlements alike. Some 40,000 EAs have been identified by COSIT in the urban areas in the 15 Provinces (except the three provinces of Kurdistan), with an estimated total number of 100,000 EAs throughout the country.

It is essential to delineate and identify the total number of EAs covering the whole country as a prerequisite to all the activities that guide the census. Since COSIT has defined the size of an EA to be between 80 and 120 buildings (and assuming that on average a household of 5.5 to 6 people occupies one building/housing unit in urban areas, but that in rural areas more than one household lives in one housing unit), the EA delineation process, using GIS and other geospatial information technologies, would be carried out in three main steps as shown in table 1.[8]

8 This methodology is reported in GIS and the 2020 Census: Modernizing Official Statistics, 2019, Esri Press, expanded and used in other similar reports prepared by the Consultant.

Table 1. Three-step method of EA delineation process

1	The first step is an initial in-office phase using satellite imagery as a backdrop. It consists of demarcating new and re-demarcating existing EAs through on-screen digitizing, editing and GIS functionality superimposing the vector data such as administrative boundaries, roads, water bodies, place names, cadastral/parcel boundaries, and other point-based features (dwellings/buildings, schools, health facilities, landmarks, etc.) on top of recent imagery at high resolution[a] of less than 5 metres, preferably less than 2 metres, and obtained within a year of the census (details on imagery in subsection 3.3). A data set of demarcated EAs is created and maps are produced and printed for the fieldworkers and used for verification in the field.
2	The second step is the field verification process: which consists of undertaking field visits across the country to correct and update in the field the data and maps prepared and created in the office. The EA boundary, size and shape will be verified against the set of principles: EA boundaries should change as little as possible so that data can be compared between consecutive censuses at the lowest level of geography possible. In the event that EAs are too large for a single enumerator, they can be split; divisions should follow reference features such as roads or water bodies where possible to minimize the need to change them at a later date. And if EAs are too small as a result of population decrease, they can be merged, though an alternative would be simply to have an enumerator work on two small EAs and then keep the boundaries consistent. Any new features on the ground will be captured as well as any suggestions of changes made to EAs should be highlighted or annotated on the map. Point-based data such as dwellings/buildings and other points of interest will also be verified and captured by GNSS/GPS handheld devices, and any changes will also be annotated.
3	The third step, following the field verification, consists of a return to the office to capture the data verified in the field, and thus create the final Enumeration Area/Supervisory Area maps to be used for the actual enumeration. Note that changes made to EAs can be confirmed only once all the updated data have been loaded, together with the annotated fieldwork maps, and an informed decision has been made in the GIS office (the updated information must be included in the GIS database). The production of EA maps can commence, in this case in the form of digital maps which can be uploaded onto the tablets.

Note: [a] The spatial resolution of a satellite image is measured by the size of a pixel on the ground which varies from the sub-one-meter of the most popular high-resolution systems to one hundred metres for low resolution systems. For most census applications, 5m or better spatial resolution is needed to identify housing units, roads, etc.

C. Use of imagery: integrating fieldwork using GPS and remotely-sensed data

Since the advent of satellite imagery with high (1m or better) spatial resolution, remote sensing (R/S) has revolutionized mapping. Satellite imagery can save countless person-hours by allowing the National Statistics Office (NSO) to focus attention on critical areas. Through integration of satellite imagery, analysts and census planners can identify areas that require additional fieldwork, for instance to account for new growth in areas surrounding cities. For planning and logistical purposes, it makes sense to identify these priority areas ahead of time to locate areas of rapid change since the last census and focus on

them; this is what is meant by the "change-detection" approach.

A satellite image has the advantage of being able to cover large areas, particularly remote areas that are otherwise inaccessible. High resolution satellite images show a level of geographic detail that is almost comparable to digital orthophoto maps created from aerial imagery, sufficient for EA delineation, provided population estimates exist for the areas delineated. Satellite imagery has an advantage when compared to other means of data collection, as usually there are no restrictions for its acquisition. However, to be fully suitable for census mapping operations, particularly the need to identify individual housing units to help delineate enumeration areas, the satellite imagery must meet certain criteria. There are some generally agreed criteria to select the appropriate satellite imagery for census operations, although they may vary depending on the country situation: (i) they should be recent, preferably acquired less than one year previously; (ii) their resolution would ideally be < 1m, but not >2.5 m, for urban and rural respectively; (iii) for the maximum allowable interference, images that contain less than 20 per cent cloud coverage should be used; and (iv) their cost should be reasonable, relative to the overall cost of the census operations. This multi-criteria selection could speed up the decision-making process of procuring and using the satellite imagery.[9]

The Global Positioning System (GPS) is a satellite-based navigation system, operated by the United States Department of Defence. There are other global navigation satellite systems (GNSS) such as the Russian GLONASS, the European Galileo or the Chinese BeiDou. The satellites give out signals that can be picked up by GNSS/GPS receivers for positioning and navigation. Such receivers are useful to capture the coordinates or location of point-based features such as physical addresses, housing units and dwellings, buildings, landmarks and other points of interest. They are particularly used for navigational and tracking purposes to ensure that the right enumeration area on the ground is visited and that the field team is actually in the right areas where it was planned that they should be.

The main reason NSOs use GNSS/GPS and remotely-sensed data at the pre-enumeration stage is to field-validate the EA boundaries that were created in the NSO GIS laboratory from the prior census's maps. Or, when accurate maps are not available, it creates a basis for EA delineation in the census main office using available recent satellite or aerial imagery, before conducting fieldwork for completion and validation. With the provisional EA boundaries superimposed over R/S imagery, the territory most in need of updating can be distinguished from areas requiring minimal updating, and with population settlements quickly located, priority areas can thus be identified. Simply put, the basic use of GPS and satellite imagery is to verify boundaries and identify new buildings and housing locations.

The use of satellite and aerial imagery by COSIT is necessary for its upcoming census, as it makes up for the lack of base maps, with recent imagery and with relatively high resolution for PHC needs. The imagery constitutes the most realistic and cost-effective option to capture multiple geographic features in a large country with desert areas like Iraq, in terms of delineation of EAs in urban and rural areas for

9 Excerpts, with some additions, from GIS and the 2020 Census: Modernizing Official Statistics.

the census. However, COSIT may opt for two types of satellite imagery acquisition: one high resolution imagery (< 4m) for the small and urban areas, and one with a spatial resolution in the range of between 4 and 10 m for rural and desert areas.[10] While the two categories are not available under free and open sources, requiring some payment if acquired from commercial providers, the latter may be less expensive and might be acquired through donors (United Nations agencies such as UN-HABITAT, UNITAR or the European Space Agency, etc.). This means we have to develop and strengthen the Imagery Processing Unit and allocate significant human and financial resources, in terms of human capacities, equipment and the acquisition of recent satellite imagery.

D. GIS and EA-based geographic database

At the core of a census GIS is the geographic database that is used primarily to create map products. However, the design of a cost-effective geographic database is enhanced when it caters to the present and future needs of the census and national stakeholders have an interest in geospatial information. This means that in some countries various agencies which collect different types of geographic data that complement the census GIS actually participate in its development in order to build upon this database after the census, including for spatial analysis and evidence-based decision making.

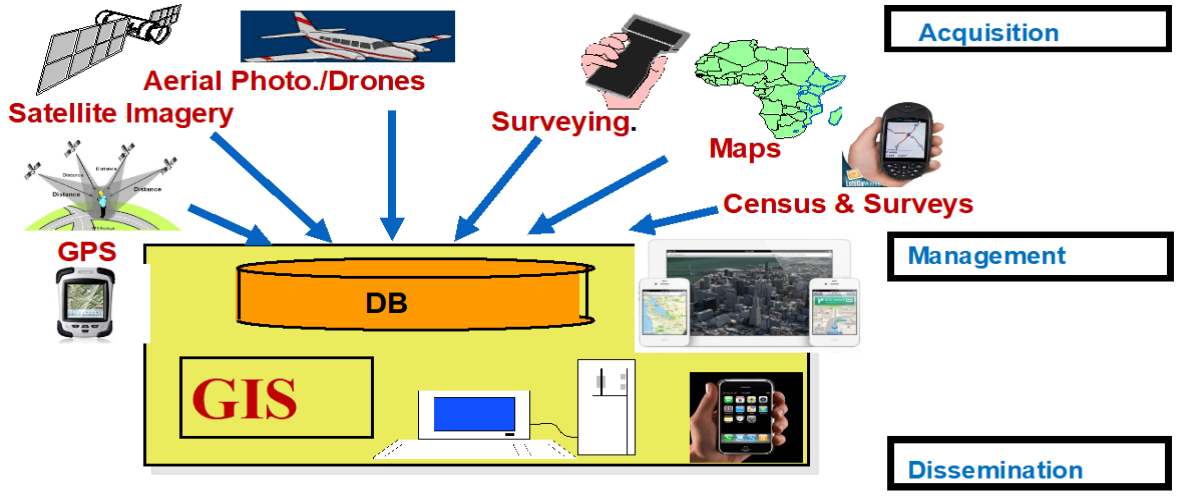
The integrative role of GIS is central. As illustrated in figure 3, satellite imagery and GNSS/GPS receivers, among other traditional tools like censuses and surveys, maps, etc., are used for geographic data acquisition. Once data are collected, they are processed and analysed using GIS, through its geographic database, in order to provide reliable information to be presented and disseminated to the users and the general public at large.

The census database contains and manages the various statistical attributes, in addition to the geographical features as defined in GIS, and it may be designed to have the capacity to evolve. We can start by focusing on the foundational features needed for the census exercise, and then link any other spatial information collected in subsequent phases and added to the database. In a population and housing census for example, beside the geographical location of the building, dwelling and/or household unit, demographic statistics captured before, during and after the census are also stored in the database for any further advanced spatial analysis and the benefit of the GIS end user.

COSIT has a GIS capability to build an EA database at the level of the smallest statistical units (EA and building); this requires building a comprehensive database and addressing issues related to the modelling and design of the geospatial database, data conversion and integration and all the other phases of geospatial data production, including the field verification and the capture of the updates and corrections, and populating the geographic database with the updated EAs.

10 "The ESA [European Space Agency] denomination relies upon the practical < 4 m, 4-10 m, 10-30 m, 30-300 m and > 300 m resolution ranges to group families of sensors. In addition to the difference in resolution, the 10-30 m range also demarcates the division between sensor data that is (predominantly) available under free and open licences and those categories (<10m) that fall within the commercial realm." Delince, Jacques and others, Handbook on Remote Sensing for Agricultural Statistics (Food and Agriculture Organization publication, 2017). Available at http://www.fao.org/3/ca6394en/ca6394en.pdf.

Figure 3. Geospatial information technologies that can be used in census activities



Source: Adapted from United Nations Statistics Division, UNSD.

The management of the actual census entails the creation of census enumeration maps as well as all other maps associated with it. Census enumeration map standards must be established in order to determine issues such as which features to include in the maps and how enumeration area maps need to be designed for efficiency and ease of use by the enumerator, bearing in mind that the EA maps created will be uploaded onto the handheld devices and used electronically.

Developing a timetable for the GIS and mapping activities is crucial, given that it is a time-bound operation with a critical date when all enumeration-related maps and map services must be made available to the census field enumeration. The situation is even more complex when we opt for the use of the CAPI method, using an electronic questionnaire, in integration with a digital EA map on the handheld device (subsection 3.6).

E. Data quality/metadata

The digitally created EA map is generally the result of the integration of data from existing (base) maps and from imagery, complemented by data captured from the field, all of which is structured and organized in the geospatial database. While the EA data is generally accurate, it must correlate with other data (e.g., topographic, built environment, transportation data) and then be integrated into the database. Since geospatial data is captured from various sources, the metadata about the maps should be well documented to be part of the data dictionary. This includes the geographic referencing information and other cartographic and imagery parameters such as the scale/resolution, projection and geographic datum, map compilation date or satellite imagery capture, compiling agency, legends, etc., that should be appropriate for use by GIS. It is advisable to adopt geostandards in line with

the international standards developed by the International Organization for Standardization Technical Committee 211 Geographic information/Geomatics (better known under its acronym ISO/TC 211), the Open Geospatial Consortium (OGC), and the International Hydrographic Organization (IHO).

As already mentioned, the development of a GIS database at the enumeration area level (or point-based level) requires the use of technology and data conversion and integration from multiple sources, and the database can be used for other purposes at the national level than the census itself, making data quality therefore crucial. Hence, the quality of these data must be analysed prior to their inclusion into the geospatial data infrastructure of NSO to support the census in order to assess their reliability and accuracy. This requires final quality checks and verification.

It is generally accepted that geospatial data accuracy refers to both positional accuracy and logical accuracy. The United Nations has indeed encouraged and recommended that each country must have a quality assurance and improvement system that should be developed as part of the overall census program and integrated with other census plans, schedules and procedures.[11] A quality assurance program that puts census authorities in a good position to identify problems and suggest improvements should include geospatial data issues. Some available administrative data sources may also be used by COSIT for the preparation of the census as well as for quality checks. It is important to note that quality data checks (control, assurance) form a continuous process that covers every stage of the census operations related to data preparation, integration, collection, processing, analysis, and dissemination.

F. Use of CAPI method/handheld devices

In a 2012 survey on national experiences for population and housing censuses of the 2010 census round conducted by the United Nations Statistics Division (UNSD), **56 per cent** of countries reported that the implementation of new technologies was the most successful aspect of the census-taking conducted for the 2010 round of censuses.[12] Innovative technologies included the use of mobile technology (handheld devices) and Internet for data collection; scanning technology; integrated systems for field management; geospatial technologies for mapping, and other web-based and mobile telephony applications for dissemination.

More specifically, the computer assisted personal interviewing (CAPI) method has been recommended as a viable alternative to replace traditional paper-based methods for census data collection.[13] The CAPI method is conducted through a small handheld electronic device, having computing power, with a mobile operating system and a display screen with keyboard. It enables census data to be captured and stored electronically, replacing the traditional census

11 Principles and Recommendations for Population and Housing Censuses.

12 Overview of National Experiences for Population and Housing Censuses of the 2010 Round (United Nations Statistics Division, 2013) available at https://unstats.un.org/unsd/censuskb20/KnowledgebaseArticle10706.aspx.

13 "CAPI is the face-to-face interviewing mode in which a computer displays the questions onscreen, the interviewer reads them to the respondent, and enters the respondent's answers into the computer". See https://ccsg.isr.umich.edu/glossary/computer-assisted-personal-interview/.

form with a series of sequential questions appearing on the handheld device screen where the enumerator enters the answer by either selecting from a predefined list of answers or entering a variable on the spot. Handheld devices, such as handheld computers, smartphones and particularly tablets, are emerging as powerful tools, improving the quality of the data collected, the timeliness of census releases and reduced costs of field operations.[14] Some recent good practices in the use of mobile technology in developing countries, such as Brazil, Cabo Verde, Egypt, Jordan, Poland, and the State of Palestine, are commended and should be emulated by other countries planning for their censuses or surveys.[15]

Most mobile devices can be equipped with GNSS/GPS capabilities, Wi-Fi and Bluetooth that can allow connections to the Internet and other Bluetooth capable devices; many can also access the Internet with mobile subscriber coverage. Handheld devices have a number of other technical options that can aid the enumerator in the census process, including equipment with camera for video player, and the ability to make telephone calls within the network coverage area, and transmit data.

Data collection via CAPI integrated with GIS offers multiple benefits but also presents certain challenges, principally the following: (i) the integration of the electronic questionnaire, enumeration areas maps, GPS,[16] transmission of data functionalities, battery, etc., must be managed before embarking on the actual use of the handheld devices in the census data collection; (ii) prior to the deployment of mobile devices, it is crucial to conduct thorough training on using not only the forms and the data collection operation, but also on the basics of the device, troubleshooting and battery life, and other issues related to the fieldwork; (iii) given the cost of a relatively important number of devices and related equipment for only limited use during the census exercise, plans need to be made for ways to reuse the equipment to enhance the gains from their beneficial use for data collection. More details on the operational side of CAPI will be provided in section 3.

In summary, in using electronic devices instead of paper maps in the upcoming census of Iraq, COSIT must ensure that the process of data collection goes as planned and it has to fulfil the responsibilities and the requirements for census activities. The use of CAPI is intended to reduce time consumption and costs in stages of the census such as traditional data entry, editing and data processing. In particular, it is required for updating the geospatial data immediately from the fieldwork and monitoring and supporting the operations of enumerators in field work in geocoding of buildings and other features of interest.

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14 United Nations. (2012) Report of the United States of America on the 2010 World Program on Population and Housing Censuses. E/CN.3/2012/2. Available at http://unstats.un. org/unsd/statcom/sc2012.htm.

15 For example, a 2017 study showed that about 57 per cent of countries in Africa were at various stages of using CAPI in census taking during the 2020 round. Preliminary Report on the Status of Country Preparedness for the 2020 Round of Population and Housing Census in Africa: 2020 Census Preparedness, African Centre for Statistics. (Economic Commission for Africa publication, n.d.) Available at https://www.uneca.org/publications/2020-census-preparedness.

16 For example, if the handheld device has integrated GPS and this is going to be used to capture the latitude and longitude of each housing unit, accuracy tests may need to be performed. The word GPS will be used in our text to indicate a satellite receiver.

G. Pilot GIS mapping exercise

The pilot census serves to test under real conditions the adequacy of the entire census plan, including cartography, methodology and applied technology such as the CAPI system and mobile devices, the census organization in general, and the interaction between all planned resources to be engaged in the actual census itself. It is recommended that the pilot census should be conducted a year before the main census, enabling a simulation of expected seasonal patterns of climate and organizational conditions.[17]

One of the major tasks of the upcoming pilot census is to test the integrated use of GIS with CAPI. With regard to the preparation of geospatial data for the pilot, the pilot/sample areas need to be selected to represent the diversity of socioeconomic and geographical conditions of the population in the country, while ensuring some balance between urban and rural areas, in order to observe the management and supervision of the field operation in real situations. COSIT may prepare around 1,000 enumeration area maps (1 per cent of the total number of EAs) to be made available for navigation and uploading onto the handheld devices (tablets) for offline/semi-online fieldwork (this is to be decided by COSIT, particularly after testing and the pilot census, as Internet connectivity maybe an issue when considering whether to opt for any real-time data collection). The GIS team must prepare and provide each EA map at the EA/building level with its related coding system and with the format required by the CAPI app.

The development of pilot census evaluation instruments must include performance indicators related to planning, field operations management and indicators related to the quality and efficiency of the questionnaires, the performance of the tablets as working tools, their endurance in the field, the transmission of data, etc.

Several insights will emerge from the pilot census and lessons will be learned from the exercise. In fact, the results of the pilot GIS mapping exercise need to be carefully analysed by COSIT to determine the potential modifications needed for the successful conduct of the actual census, including the appropriate CAPI to be selected and its integration with GIS. Issues raised by the outcome of the pilot will need to resolved by subsequent activities.

H. Technical solution

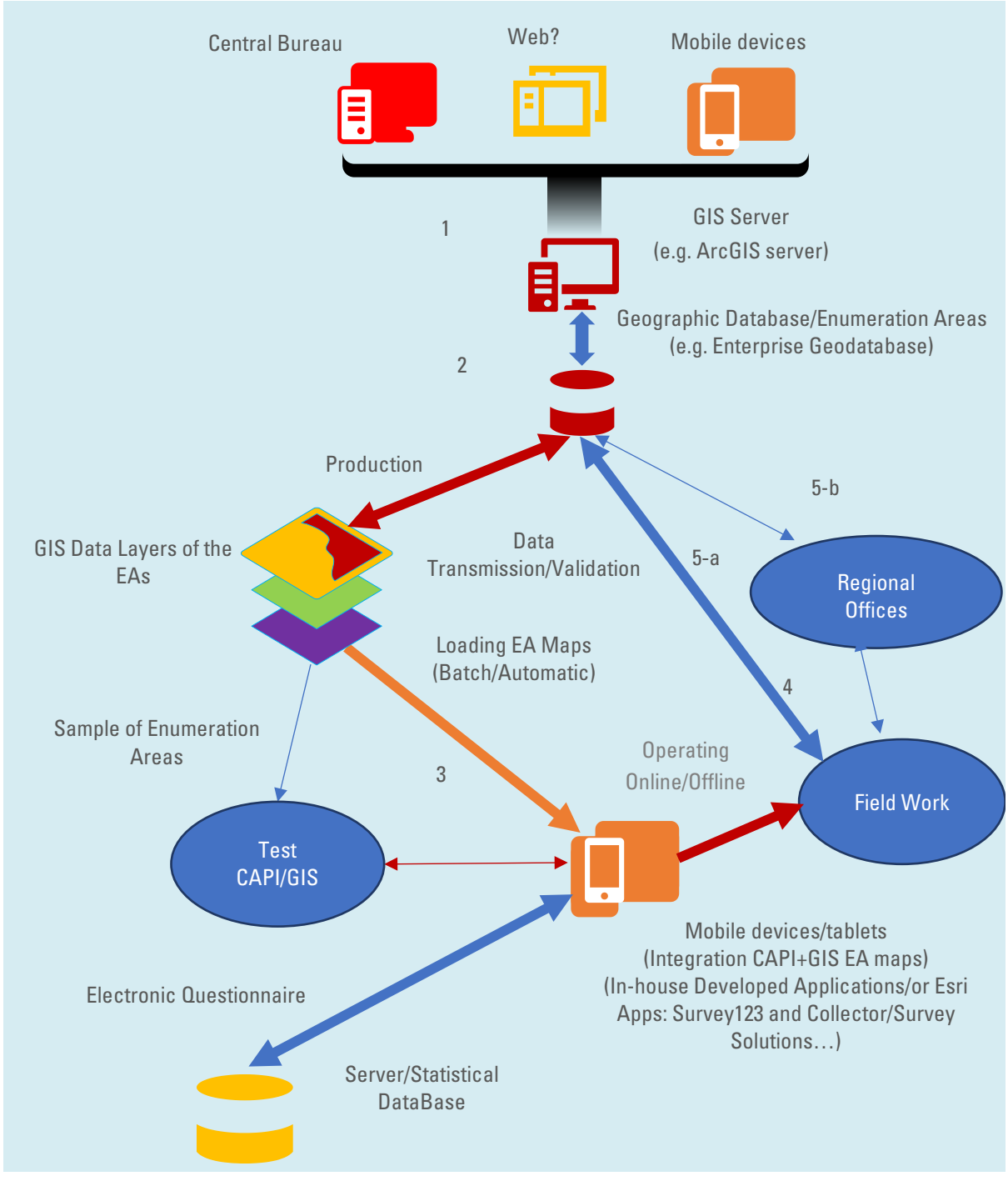
To cater to the needs of the census mapping program, we propose a technical solution, a mobile GIS solution to be implement by the GIS/IT team. This solution allows the integration of the different GIS data layers, relating to the EA/counting areas, with CAPI applications to choose or develop, the fieldwork, and the transmission of the data collected to the central system. The following schema (figure 4) provides the general view of the workflow as outlined in five major components (table 2).

17 Principles and Recommendations for Population and Housing Censuses.

Table 2. Technical solution for the data preparation and collection workflow

1	Pre-enumeration geospatial data collection, organization and structuring in a geospatial database at the EA/building levels As stated in sections 2 and 3, at the pre-enumeration stage, COSIT needs to do an inventory of the existing data and collect the additional needed data from multiple sources. Once data is collected, it should be integrated, and organized to create the EA-based database.
2	Production of the EA maps As previously mentioned GIS will be used during the pre-enumeration stage to build the most complete and accurate delineation of administrative and EA units and produce the best possible quality EA maps to be used during enumeration. All EA maps should be simple and clear and easy for the enumerator and field supervisor to use. EA maps typically contain: (i) geographic features on base maps, such as streets and roads, buildings, major water bodies, topographic and other hydrologic features, and any map annotations; (ii) EA boundaries; and (iii) points of interest for orientation using symbols (e.g. mosques, schools, hospitals, landmarks, etc.).
3	Integration of CAPI with GIS-based EA maps Since COSIT has already planned to use tablets for the map updating operations in the field, a computer-based application must be used (developed or selected) and loaded onto the handheld devices, providing editing tools for the geometrical and other descriptive data of EAs, buildings and dwellings, in addition to providing GIS functionalities for the capture and editing of the various GIS layers, notably buildings, streets and other reference points. In terms of the preparation needed for the use of handheld devices for fieldwork, the essential activity is uploading the EA maps onto the tablets to be used in combination with the electronic questionnaire forms. The uploading of the final EA maps to be used for data collection will follow the tests undertaken by the pilot census and any subsequent adjustments.
4	Field operations management The fieldwork begins once CAPI and the GIS-based maps are integrated and ready to operate.
5	Data transmission and validation This step relates to data transmission and interaction with the central system. There are two options for the flow of data transmission: either directly from the field to the central system (5-a), or through a regional office as intermediary data centres before the ultimate transmission to the central system (5-b). Steps 4 and 5 are more detailed in the following section 4.

Figure 4. Diagram of the proposed technical solution



Source: Prepared by consultant.

3. Supporting and implementing data collection and helping to monitor census activities for the enumeration phase

As COSIT has opted to use the CAPI method at the enumeration stage, this means relying on map services and mobile map packages more than on printed maps. Therefore, we need to create or use mobile map packages to upload the enumeration area (EA) maps onto the device which will enable the enumerators to visualize the EA maps, helping them in their field orientation and in finding the correct housing units within their assigned enumeration areas.

Mobile apps enable a user to download map areas where connectivity is available, show the user's GPS location, and with a simple tap on the feature (dwelling or housing unit) add information about the location and accurately capture statistical data, filling in the electronic questionnaire related to the household in question. Then enumerators transmit the data collected online, feeding directly into GIS, or save it until the end of the day or such time as they are back in connected range to send to the central office. Using the EA maps and the electronic questionnaires filled out by enumerators, along with GPS points collected on the device, allows COSIT staff to verify the data collected and determine whether EAs were fully covered.

Mobile technology has the advantage of being able to feed data collected from each device to the central database in real time (or near real time). With GPS enabled handheld devices, census managers can locate and track the location of the enumerator, monitor the progress of the enumeration and identify areas where there are gaps, and enumeration is falling behind, which households the enumerators may need to revisit, or which enumeration is not meeting quality standards. These capabilities allow COSIT to streamline and automate field operations, through dashboards, and thereby improve their management and the quality of the census itself. GIS-based analysis of EAs helps optimize the workload assignment; GIS also provides tools for solving complex routing problems and can be used to create suggested routes for the fieldworkers.

The computer application is generally designed with a set of logical rules that improve the quality of the map updating operations. Ideally, fieldworkers should be allowed to select different GIS layers to edit (layer of buildings, layer of streets, layer of landmarks), and within each layer, each spatial feature. Since COSIT wants to capture the point-based features such as the buildings, the computer application for how to conceive or select map updating must be used not only for the 2021 census project, but also in future statistical activities of COSIT, for instance to support the preparation of sample-based surveys, and in the creation or updating of the register of buildings and dwellings.

4. Contributing to statistical analyses and dissemination for the post-enumeration phase

A census is a major undertaking necessitating considerable effort to collect census data; however, these efforts will not bear fruit and impact policy decisions unless the census information is made available in a suitable format to the various users. Maximizing the use of census results demands a dissemination strategy implemented through a well-prepared dissemination programme designed to reach a wider audience, including the media and the public.

With the rise of information technology capabilities, digital products are replacing traditional publications, so that the dissemination strategy will need to take into consideration the diversification of the means of distribution, to cater to the needs of a wide range of users, including government agencies and major users, as well as citizens, civil society, researchers, academia, developers and others.

The strategy should also include key elements such as determining the geographic level at which census data will be disseminated, identifying the census and geography products and services to be delivered, establishing a schedule for the main dissemination operations with their estimated costs and the human and technological resources that will be needed to carry them out. In addition to ensuring that the disseminated census products are of sufficient quality to fulfil user needs, safeguards should be put in place to keep individual information private and confidential.

Since COSIT will use GIS from the pre-enumeration stage, it will benefit from the simple and easy methods GIS offers to put census data on maps that enhance their understanding and enable users to visualize statistical information. Moreover, GIS enables the presentation of census results in different forms – charts, graphs, dashboards, thematic maps, map applications, smart and story maps. In addition, GIS enables maps to be easily exchanged in digital format on the Internet, and to implement web-based applications.

With the establishment of a geospatial census database at EA and buildings levels, GIS provides powerful tools to proceed with spatial analysis, enabling the user to create various census and geographic products to be disseminated successfully. In addition, the use of mobile technology and the WebGIS applications, the census data dissemination will put COSIT census data at the fingertips of the major users, and even the public in general. In particular, thematic maps for dissemination are generally produced not only for the major census data users, but also for a

wider, non-specialist audience. Thematic maps are also often intended to support textual information accompanying census reports. Moreover, in the case of Iraq, thematic maps in an electronic (interactive) atlas can present census data and many indicators at the country level, administrative units and any human settlements.

5. Operational guidelines and capacity development

A. Guidelines on the use of GIS and other geospatial technology at every stage of the census

The use of GIS in the census process offers many benefits as it spans every stage of the census. At the pre-enumeration stage, GIS is used for the delineation of EAs and building the census geographic database, the EA GIS-based maps are prepared for integration with the (electronic) questionnaire on a handheld device and used for the pilot census, and eventually for field enumeration. At the enumeration stage, in addition to the provision of EA maps, GIS is used to support fieldwork in managing field operations, including optimizing workloads and routes. At the post-enumeration stage, GIS provides spatial analysis and assists in the creation of products for dissemination with advanced tools of visualization, dashboards, and other smart/story maps.

In table 3 all the practical procedures are summarized as steps that should be followed one by one in the use of GIS, although some of the steps can be conducted simultaneously. These recommended steps are not carved in stone as COSIT may need to make adjustments depending on its national conditions in terms of infrastructure, capacities, and institutional arrangements, and eventually select what it deems suitable.

Table 3. Guidelines on the use of geospatial and mapping activities at every stage of the census

	Activity	Procedures
Supporting and implementing geospatial activities for the pre-enumeration phase	Delineation of EAs	The EA delineation process, using GIS and other geospatial information technologies, is carried out in three main steps as described in section 3.
	Building the GIS/EA-based census geographic database	This is the process of building a geographic database which is the foundational core of any GIS. In the case of Iraq, it refers to a census GIS database at EA and point-based (building) levels. In creating the census GIS database, we start by identifying the components of a census geographic database (i.e., determine data layers to be created), emphasising the different stages in its development (some in parallel). They include a geographic data inventory for EA delineation; geographic data conversion through scanning, digitizing or use of earth observation data; construction and maintenance of topology; georeferencing and geocoding geographic

	Activity	Procedures
		features, integration of various digital data; developing conceptual database design and data models; identifying accuracy requirements and standards; implementation of the EA database; developing the data dictionary and metadata guidelines (including data dictionary) for quality control/quality assurance. The census GIS database can be designed on an evolving basis. We can start by focusing on the foundational features needed for the census exercise, and then link any other spatial information collected in subsequent phases and added to the database. For example, besides the geographic location of the building, dwelling and/or household unit, demographic statistics captured before, during and after the census are also stored in the database for the benefit of the GIS end user. The changes made to EAs in the third step of their delineation detailed above can only be confirmed once all the updated data has been loaded, together with the annotated fieldwork maps, following an informed decision made in the (GIS) office. Once the updated information has been included in the GIS database, map production can commence.
	Integration of GIS with CAPI	Integrating GIS with CAPI is a very complex technical operation. Because this not part of COSIT core business, it is advisable to conduct it through partnership. The CAPI approach, using a handheld device equipped with in-built GNSS/GPS receiver and the integration of GIS-based EA maps, requires the following: • Development or selection by the IT team of a CAPI app. • Preparation of mobile GIS-based EA maps. • Uploading of the EA maps onto the handheld devices (mobile map packages to be used online, offline or semi-online depending on the availability or not of Internet connectivity, or slow network speeds). • The integration of the electronic questionnaire, enumeration areas maps, GPS, transmission of data functionalities, battery, etc., before embarking on the actual use of the handheld devices in the census data collection. • Prior to the deployment of mobile devices, it is crucial to conduct thorough training on using not only the forms and the data collection operation, but also on the basics of the device, troubleshooting and battery life.
	Pilot GIS mapping exercise	• The pilot census serves to test in real conditions the adequacy of the entire census plan, including the cartography, and the technology applied, such as the CAPI system and mobile devices. The pilot GIS mapping exercise include the following steps: • In preparing geospatial data for the pilot census, pilot areas should

	Activity	Procedures
		be selected to represent the diversity of socioeconomic and geographical conditions of the population in the country (e.g. in urban and rural; in cities and small localities), to observe the management and supervision of the field operations in real situations. • Preparation by the GIS team and provision of each pilot EA map at the EA/building level with its related coding system and in the format required by the CAPI app. • Testing the integration of GIS with CAPI. • The results of the pilot GIS mapping exercise need to be carefully analysed by COSIT to determine the potential modifications for the successful conduct of the actual census, including the appropriate CAPI app to be selected and its integration with GIS.
	Other planning activities with GIS	Additional activities benefiting from the use of GIS include optimizing EAs in using spatial analysis, optimizing site placement of field offices, and asset distribution, etc.
Supporting and implementing data collection and helping to monitor census activities for the enumeration phase	Mobile GIS for field data collection	Handheld devices are used for field data collection where, in support of the CAPI enumeration process, the GIS-based EA maps are uploaded onto the device and combined with satellite or aerial images as backdrop. This allows the enumerators to visualize the EA maps, helping them in their field orientation and to find the correct housing units within their assigned enumeration areas. Using the EA maps and the electronic questionnaires filled out by enumerators, along with GPS points collected on the device allows COSIT to verify the data collected, and whether the EAs were fully covered. Ideally, once the data have been transmitted to the COSIT central data centre, data including geocodes are entered into the GIS census database, providing information about the progress of the census coverage (for example, on the open source side, there is Survey Solutions developed under the auspices of the World Bank, and on the commercial side, there are the Esri CAPI tools, Survey123 for ArcGIS and Collector).
	Monitoring census activities	GIS is used on mobile devices to support field operations management in streamlining and automating field operations, such as monitoring the workflow of timely information to and from the field enabling census managers to be informed of the progress of data collection and at the same time providing enumerators with updates. In addition, it helps to track the location of the enumerators and advise about their gaps; to optimize both the workload assignment and the routes (telling the enumerators where to go and the best route to take); and in particular, to monitor the progress of census operations including identifying trouble spots.

	Activity	Procedures
	Updating EA maps/updating geographic database	GIS/GPS and imagery are used during the fieldwork of the enumeration phase for a final update of EAs to insert any updates and corrections to the enumeration areas into the master database. Traditionally, the census cartographic staff would collect the EA maps after the census and incorporate the edits into the master database; this task can be tedious and may impact the timeframe of the census results. But with the digital enumeration approach, this operation can be automated, provided that an application is used with field edits being captured interactively. Editing and updates captured in this manner can easily be verified and then incorporated into the database in a much more streamlined fashion. Updating the GIS census database would serve for post-enumeration and inter-census activities.
Contributing to statistical analyses and dissemination for the post-enumeration phase	Interactive maps/atlases/ geoportals	To maximize the use of census results and make them available in a suitable format to the various users, a dissemination strategy should be prepared (at an early stage) for implementation through a sound dissemination programme, as recommended by the United Nations. The Statistics Office needs to take advantage of the rise of information technology capabilities to enhance the dissemination and sharing of census data and information to reach a wider audience, including government agencies and major users, as well as citizens, civil society, researchers, academia, developers and others. Initially, GIS has been used by NSOs for the dissemination of their geographic products, mainly through maps. But, in addition to the GIS mapping capacities, COSIT can use it for the following: • Thematic maps and interactive atlases: thematic maps for dissemination are generally produced not only for the major census data users, but also for a wider, non-specialist audience. Thematic maps in an (electronic) interactive atlas can present census data and many indicators at the country level, regions, large cities, municipalities and human settlements. In addition, (geo)portals will prove useful as they are a cost-effective mechanism for marketing and continued delivery of useful census and geography products and services to a diverse user base, that can go far beyond the initial post-census period. • Web mapping/WebGIS/story maps/smart maps. Web mapping is more than traditional mapping, as it is a service whereby users can choose and customize what the map will show. This is provided by smart mapping, using computation and analysis to automate the creation of maps, to accommodate users who are not necessarily familiar with GIS. The trend in web mapping is to cater to the needs of users who want to create fully interactive web maps that communicate meaningful and compelling stories from their data.

	Activity	Procedures
		• Web mapping is the process of using the maps delivered by GIS on the Internet (Web), where the web map is both served and consumed (See Wikipedia). But, instead of web GIS systems that try to cover everything, the now accepted best practice is to build a story map that answers one particular data related question or workflow. • Spatial analysis: with the building of a geospatial census database at the EA level, GIS provides powerful tools to proceed with spatial analysis, allowing the user to create various census and geographic products to be disseminated in accordance with cartographic and metadata standards. • Supporting surveys and sampling frame. • Geospatial information is also instrumental in other statistical activities, such as the creation of a georeferenced national dwelling framework to identify and locate (geographic coordinates) all structures on the ground, the establishment of a national register of buildings and dwellings, the development of a business framework for use in an economic census, the improvement of the coverage in (land) parcel units and the building of the National Spatial Data Infrastructure (NSDI). Geospatial information supports the maintenance of these frameworks which are required for use as a basis for the statistical sampling frame for inter-censal surveys and future censuses.

B. Manuals and training/capacity building

Under the operational guidelines on how to use geospatial information technologies at every stage of the census, resources and capacities must be identified to ensure their implementation and monitoring. In particular, since census mapping is a specific activity different from regular cartographic activities which are generally not a core business for most of the national statistical organizations, mapping staff need to undergo training on mapping procedures. A very important component for the enumerators is to be educated on using the survey application and forms on the device as well as the entire process of data collection, including the basics of the device and how to troubleshoot. As they are using GPS to obtain point feature locations, mapping staff need to be trained on the procedure for collection and storage of these locations. Likewise, since a list of buildings and dwellings is to be compiled alongside the mapping, the field staff need to be trained on identification and location of the buildings and dwellings.

The field and census mapping work requires manual support. Guidelines and reference manuals will be put in place, including requirements relating to accuracy and census enumeration map standards, the data dictionary and metadata, the procedures to upload EA

maps and the use of handheld devices with the in-built GPS receivers, and to the final output products. If we opt for the services and commercial products, a help-line and vendor support should be provided.

Building technical and human capacities needed for sustaining the GIS-based census programme requires training of census geography staff to equip them with appropriate skills in GIS to serve all census geography/mapping needs. We need to provide training of trainers for census mapping and geospatial information technology, who in turn will conduct the trainings of the trainees when needed.

Well-trained staff are a key factor in the success of GIS-based census mapping projects, but in order to retain them, COSIT needs to provide significant incentives and ensure continuous training to keep them abreast of advances in technology. For the upcoming census, specific training sessions are to be conducted, and in addition, at least a study visit should be organized for some participants to a country with good practice in the use of GIS and handheld devices for data collection, including at the point-based level. In this regard, it would be advisable to select a country similar to Iraq, which has had a good experience with its last census undertaking in recent years.

6. Road map for planned census mapping activities

A full digital GIS-based census requires a detailed road map outlining the activities to be carried out at every stage of the census. In table 4, the planned census mapping activities are presented in detail by main phases: activities for the pre-enumeration phase, the enumeration phase and the post-enumeration phase. The following activities are critical to the success of a full digital and GIS-based census mapping exercise: (i) ensuring awareness that building a long-term digital census mapping programme should be a strategic decision that requires commitment from the high-level decision makers in the country; (ii) building technical and human capacities required for sustaining the census mapping program and establishing well equipped teams for cartography/GIS activities within COSIT to maintain the GIS database and mapping infrastructure, and keeping abreast of advances in technology; (iii) developing a partnership for cooperation with other organizations involved in geospatial information activities to build a national statistical and geospatial information infrastructure in support of decision making and sustainable development. These recommendations are mainly derived from lessons learned from country experiences during the last 2010 round of censuses.[18]

Table 4. List of census mapping and geospatial activities for pre-enumeration phase, enumeration and post

	Activity description
1	Geospatial activities to ensure coverage and facilitate census planning process for the pre-enumeration phase
1.1	Inventory of existing maps and geospatial data in all its forms
1.2	Definition of census geography and updating boundaries and coding, the hierarchical structure of administrative, statistical and geographic units
1.3	Delineating/updating EA boundaries and coding of spatial units/geocoding
1.4	Building/updating the EA-based census geodatabase
1.5	Strengthening/building IT infrastructure for geospatial activities (software updating and/or new acquisitions; hardware upgrading and/or new acquisitions)

18 UNFPA Strategy for the 2020 Round of Population and Housing Censuses 2015-2024 (United Nations Population Fund publication, 2019). Available at https://www.unfpa.org/publications/unfpa-strategy-2020-round-population-housing-censuses-2015-2024.

	Activity description
1.6	Identification of the mapping requirements for the CAPI app in order to integrate GIS-based EA maps for use on mobile devices (mobile map packages) on an offline mode
1.7	Preparations for map updating activities (field organization, staff, training, manuals, tablets)
1.8	Map updating in the field (surveyors)
1.9	Updating of EA boundaries and coding of spatial units/geocoding
1.10	Editing and quality checks of the census geodatabase and delineation of supervisory areas
1.11	Preparation of EA maps to be made available for use by CAPI app on mobile devices, including for the pilot census
1.12	Map updating in selected areas by COSIT/GIS team
2	Data collection and monitoring of census activities for the enumeration phase
2.1	Selection (or development) of the apps for field management, monitoring and tracking system, including evaluation and testing
2.2	Preparation of digital EA maps and upload into tablets for the enumeration operation
2.3	Selection and training activities (trainers) for assistants on field mapping
2.4	Field support and map updating during data collection operation
3	Mapping activities for the post-enumeration phase. Contribution on statistical analyses and dissemination
3.1	Preparation of a strategy for the dissemination of the geospatial data/information (a component of the overall census dissemination strategy)
3.2	Preparation of geospatial data for the post-enumeration surveys (PES) – Link census and PES data with geospatial data for the census evaluation
3.3	Linking census data with geospatial data and updating the census geodatabase
3.4	Preparation of the new sample frame
3.5	Use of geospatial information for census dissemination and analysis
3.6	Creation of thematic maps for data dissemination in census reports, including a paper and an electronic atlas
3.7	Preparation of a geoportal – WebGIS with story/smart maps
3.8	Developing a metadata system at COSIT on metadata standards in line with international standards
3.9	Trainings for (major) census users on the use of geospatial information at central and local levels

7. Conclusion and recommendations

Geospatial information technologies have greatly improved and become more accessible and affordable, rendering hand-drawn maps less used than in the past, and the use of GIS, GPS, satellite/drone imagery and automated digital field map creation has almost become the current norm. In the 2010 census round and even more in the current 2020 round, countries adopted these new technologies with varying levels of success. There are a few considerations which need to be taken into account for a GIS-based census to be truly successful. With the right mix of resources and skills, countries can greatly improve their map production and field monitoring to collect with more precision and quality population and housing data for the census, and the building of a well-structured geographic database at the smallest statistical unit which can be extremely useful for other applications at the national level.

For COSIT to achieve a successful outcome with the mapping exercise, a strong team skilled in imagery and remote sensing must be established and given the appropriate equipment to complete the imagery processing tasks. In particular, an imagery processing unit is required for example to use satellite imagery to make up for the lack of base maps and assist in uploading the images as a backdrop on the tablets. In this regard, COSIT needs capacities in imagery processing and some form of external technical assistance needs to be considered.

For the mapping activities for its upcoming census, COSIT plans to adopt an integrated electronic system approach composed of GIS tools and tablets for EA boundaries updating and numbering of buildings. The system is also intended to be linked with the CAPI applications to be used for the enumeration process, and to support the field management and monitoring activities. The system will in addition support the preparation and implementation of the post-enumeration survey and the dissemination of census results and geographic products.

It must be emphasized that the integration of CAPI with GIS is not an easy task; it requires specific skills and capacities for this demanding work, so that few NSOs have them all in-house. At the institutional and organizational levels, well-trained employees in the use of the panoply of technologies (GIS, GPS, Imagery and IT) of GIS and IT units are required within the national statistical organization (NSO), otherwise CSOIT may need to opt for outsourcing or contracting out some or all of the elements of preparation of census maps,[19] as COSIT needs to process satellite imagery to create them, as well as their integration with CAPI. If COSIT deems that its GIS capacities are not sufficiently trained and it can only be offered limited support, it should opt for outsourcing and seek an external partnership. However, COSIT should define the terms of reference for external consultancies and develop mechanisms to control and evaluate the various activities to

19 Principles and Recommendations for Population and Housing Censuses, pp. 94-95.

be outsourced, principally the security of the data to be collected.

Finally, we summarize the findings, issues and potential solutions in table 5.

Table 5. Main findings, issues, potential solutions and the way forward

	Task/ observation	Issue	Potential solution	Way forward
1	Base map	Lack of updated Base maps.	Update by: use of satellite imagery using an optimal solution: high resolution (<4m) vs intermediate resolution (4-10m) enabling image processing for making up base maps for the delineation of EAs.	Developing the use of imagery, including unmanned aerial vehicles (UAV)/drones.
2	Enumeration areas and geocoding	What geographic frame for PHC? And how to proceed with the delineation of EAs, covering the whole country?	Adopting a geocoding scheme for PHC capable of fulfilling the needs of the upcoming census and beyond. Using satellite imagery and any existing admin maps and GIS for the delineation of EAs, covering the whole country. Most of the work to be done in-office, then validation in the field. (3-step method – guidelines in the report).	Adapting the coding scheme with the future changes and developments.
3	Geographic database	What geographic layers do we include in the EA/building-level database?	Updating the EA level geographic database with the population of EAs into the database. (COSIT has identified approximately 40,000 EAs in the urban areas in 15 provinces, 100,000 throughout the country). Constitutes the fundamental basis for a GIS.	A gradual continuous process.
4	GIS/software	What kind of GIS software to be used: commercial vs open source (e.g., QGIS).	The census requires an enterprise system, with periodic maintenance and security. Capitalize on what is existing, but in a formal way: ArcGIS Enterprise and ArcGIS online.	An interoperable system with various Ministries and national organizations.
5	Linkages of IT and GIS software	Integration of CAPI and GIS EA Maps.	Technical solution (figure 3).	To be adjusted after the pilot census.

	Task/ observation	Issue	Potential solution	Way forward
6	Pilot census GIS exercise	How many EAs to be selected for the pilot and what apps are needed?	Proceed with prototyping the use of CAPI and GIS in the field, to test the technical solution (including in-house developed apps, survey solutions and Esri Suite).	The pilot census will determine the final apps to be used and the technical solution.
7	Capacity development	Need to develop GIS/IT capacities and to keep them abreast of the latest technological developments.	Train GIS/IT staff and acquire needed equipment.	Maintain training/incentives to GIS staff to retain them at COSIT.
8	Technical Assistance	The integration of CAPI with GIS is arduous and requires various skills.	Resort to technical assistance and possible outsourcing of some technical tasks.	Take all the measures for security and privacy/confidentiality of data and systems, particularly when we proceed with outsourcing (through ToRs and contracts).

Annex 1. Brief Questionnaire: A request for COSIT Centre for GIS[20]

Please respond to the following questions designed to assist in establishing an inventory of the status of mapping and geospatial infrastructure in Iraq, as COSIT is the main provider of geospatial data for the census. Thank you in advance for your valuable contribution!

Steps to follow in checking a box:

A. Left double-click on the box.
B. Select "Checked" for default value.
C. Click "OK".

A. Please tick the relevant box if you have any of these categories of map:

☐	Small scale maps (national map overview): Showing the major administrative area boundaries, the location of major features, including large settlements and places, important transportation networks, water bodies, and important points of reference and other landmarks.
☐	Topographic maps: Showing elevation contours and other major topographic features.
☐	City and cadastral maps: Showing land parcels, details about important features such as transportation networks, parks, water features, points of interest such as schools, hospitals and police stations as well as important city buildings and landmarks.
☒	Maps of administrative units: Showing administrative unit boundaries at all levels of civil divisions.
☐	Thematic maps: Showing population distribution for previous census dates, or any features that may be useful for census mapping.
	Please provide for each category the scale, date, source, projection, etc.
	The maps of administrative source by General Authority of Survey.
Scale	1:250000M
Date	2002

20 Prepared by Amor Laaribi, Consultant.

B. Please tick the relevant box if you have any of the following forms of imagery:

☐	Aerial photography
☐	Orthophotos/Orthophoto maps
☒	Satellite imagery
Please indicate the resolution/scale of these satellite images/digital aerial photos, the source/mode/date of their acquisition and their coverage.	
Source	World view satellite imagery
Date	2018-2019
Coverage	The entire Iraq area, both urban and rural, around 270,000 km^2, but without desert region

C. How are the map products delivered?

☒	in hard copy
☒	in digital form
☐	online
☐	online by web services

D. Is mapping and map updating done in-house or by outsourcing?

We are updating the maps in our house only (CSO/GIS UNIT).

E. What Datum and National Geodetic/Spatial Reference System?

UTM WGS 1984 ZONE 37, 38 and 39.

F. Software:

Please name the GIS software used in your organization	
1	Esri Products:
☒	ArcGIS Desktop
☒	ArcGIS Enterprise
☐	ArcGIS Online
☐	ArcGIS Pro
2	Other (please specify)
	ArcGIS Image Server
Please indicate whether you have a geographic database? And if yes, was it at the EA level?	
	Yes, we have personal geodatabase for multi-layers, but not at EA level

G. Infrastructure/Equipment

☒	Does your Organization have a GIS Unit, and with how many people? Yes, CSO/GIS unit and the staff now numbers around 40 people.
☒	What kind of hardware do you have (desktops, workstations, plotters, scanners, printers, other)? Desktops, laptops, scanners, plotters and printers.
☒	Do you have and use GPS devices? Please specify We don't have GPS devices in GIS unite, but the staff used it.
☒	Is there a digital elevation model (DTN) available? Please specify No.

H. Do you have GIS-based applications and/or GeoPortal/Web-based mapping tools?

No.

I. Do you have other geospatial data such as gazetteers-place/geographical name?

No.

J. Are you using ISO/TC 211 Geo-standards and/or OGC standards?

No.

K. Any other mapping/geospatial services?

Not yet.

Annex 2. Responses to ESCWA Questionnaire 2018-2019

Respondent Firas Rasheed, firasgisc27@gmail.com

Part B: National Statistical Geospatial Information Capability	
Q1	Describe the organizational structure of geospatial information capability in your country. For example, is there a single National Geospatial Information Authority (NGIA)? Do other areas of government also have geospatial information capabilities and/or responsibilities?
R1	There is no single national authority for geospatial information in Iraq, as some service institutions have GIS departments that assume responsibilities related to the tasks of those institutions in the Iraqi Central Bureau of Statistics. Statistics also participate in supporting the field work of the Ministry of Planning and assisting researchers from outside the institution and graduate students in the field of geographic information systems.
Q2	Is the primary national geospatial agency supporting/advancing the geospatial enablement of government information-statistics and/or administrative data?
R2	No. There is no National Geographic Agency in Iraq.
Q3	Does your National Statistics Office (NSO) have any relationships and/or collaborative activities with NGIA?
R3	No.
Q4	Does your NSO take a leadership role in geospatially enabling national administrative and statistical data?
R4	No.
Q5	If no, what organization in your country undertakes this role?
R5	There is no National Authority for Geospatial Information, as the GIS Centre is linked to the Iraqi Central Bureau of Statistics that carries out all the geographical works of the National Statistics Office as well as supports some other geographic institutions.
Q6	Do you have a specific geography or geospatial unit?
R6	Yes.
Q7	If yes, does this group produce only maps or does it undertake other geospatial activities to support the NSO?

R7	It produces maps as well as other geospatial activities that support the National Statistics office.
Q8	If yes, does it support organizations and activities outside the NSO?
R8	It supports activities outside the scope of the National Statistics Office, for example support for other government institutions, researchers from outside and government institutions, and undergraduate and postgraduate students.
Q9	Please describe the geospatial framework that you use in the Organization's activities.
R9	All lands of the Iraqi state with the exception of the governorates of the Kurdistan region and for the following layers (primary divisions, buildings and constructions, streets, water resources, urban expansion, slum settlement sites, and sectoral projects in Iraq).
Q10	Do you use different levels (scales) of geographies?
R10	Yes.
Q11	If yes, how does each level relate to each other?
R11	The levels are linked by a Geospatial Database.
Q12	Do you have geospatial attributes linked to the statistical information (unit level records and statistical outputs) in your organization's data management systems?
R12	Yes.
Q12-1	If yes, could you explain what types of geospatial attributes you attach to the unit record and statistical aggregation?
R12-1	The geographic characteristics that are attached to the unit record are distance and length data and geolocation data.
Q13	What approach (and what systems) do you use to geocode your unit level data?
R13	A non-geospatial code was used commonly by all linking the statistical unit data, consisting of 12 places.
Q14	Do you apply any specific geographic administrative boundaries to your statistical information – such as suburb, local government or other boundaries?
R14	Yes, geographical administrative limits are applied to statistical information.
Q15	Do these geographic boundaries ever change and if they do, do you track these changes over time?
R15	Yes, the administrative boundaries change and these changes are followed over time.
Q16	Do you produce any geospatial map-based outputs?
R16	Yes.

Q17	If yes, briefly describe these.
R17	Technical Reports 'Maps' A statistical and paper atlas.
Q18	Do you produce any other type of output that could be considered geospatial?
R18	Yes.
Q19	If yes, briefly describe these.
R19	Estimates of agricultural crops, census of palm trees, report of damages to residential buildings in the stricken cities, reconstruction and development projects, and investment land allocation projects.
Q20	Is any form of geospatial capability used in relation to creating statistics, or in their analysis?
R20	No.
Part C: Technological tools	
Q21	What technological tools has the national statistics office/census office used for the dissemination of census results? (Check all that is applicable).
☒	CD-ROM/DVD.
☒	Static web pages (html, PDF, excel).
☒	Census Atlas (Static)/Thematic Map.
☐	Interactive Census Atlas.
☒	Queryable database(s).
☐	Online database(s).
☐	Dynamic web pages.
☐	GIS web-based mapping tools.
☐	Cloud Computing.
☐	IHSN[a] Toolkit.
☐	Others (please specify).
Q22	Does the national statistics office/census office employ interactive tools for mapping, tabulating, analyzing and presenting data in graphs or other visual formats in the dissemination of census data?
R22	No.
Q23	Does the national statistics office/census office employ mobile technology applications and the new social media (Twitter, Facebook, SMS, etc.) in reaching users? Yes☒ No☐

	If yes, describe the technologies and social media employed. Facebook.
Part D: Geographic information system (gis)	
Q24	Does the national statistics office/census office have GIS infrastructure to capture, manage, analyze and disseminate geo-referenced data? Yes☐ No☒
Q25	Does the national statistics office/census office have a geographic/cartographic unit (with trained human resources and the requisite IT infrastructure) dedicated to managing the geographic information system? Yes☒ No☐
Q26	Indicate the census activities towards which the geographic information system is used (check all that are applicable):
☒	Cartography/census mapping in the initial stages of census operation (pre-enumeration stage).
☒	Census data collection (enumeration stage).
☒	Analysis and dissemination of geo-referenced census data (post-enumeration stage).
Q27	Does the national statistics office/census office disseminate georeferenced data? Yes☒ No☐ If yes, what is the smallest geographical level at which geo-referenced data are disseminated? Smallest level to be published (Governorate).
Part E: Dissemination and archiving strategy	
Q28	Has the national statistics office/census office developed a written plan/strategy for the dissemination of census data? Yes☐ No☒
Q29	Did the national statistics office/census office develop a dissemination schedule (a comprehensive list of census outputs with accompanying timetable)? Yes☐ No☒
Q30	Does your country have a law/regulation for archiving census microdata? Yes☐ No☒
Part F: Data confidentiality and annonymization	
Q31	Does the statistical law of your country include clause(s) to ensure confidentiality of census microdata? Yes☐ No☒
R31	If yes, please describe the clause(s):

	Law 21 of 1972 amending not to publish transactions and data that pertain to a concerned person or a company concerned with the specificity beyond his or her written consent. Describe what procedures have been implemented or plan to be implemented for anonymization of census micro-data: It is personal information from databases when used for scientific research and publishing purposes.
Part G: Meta-data and documentation	
Q32	Does the national statistics office/census office provide metadata (information about census data and census methods) with census products? Yes☒ No☐
R32	If yes, what kinds of metadata are provided? (Check all that is applicable): ☒ Data source (census methodology). ☒ Variables and definitions. ☐ Structure and formatting of the dataset. ☒ Coding instructions and classifications. ☐ Data processing procedures. ☐ Evaluation of data quality. ☐ Confidentiality and anonymization[b] procedures. ☒ Sampling methodology and weighting. ☐ Other-Specify _____.
Part H: Challenges	
Q33	What are the main challenges faced by the national statistics office/census office in the dissemination of census data?
R33	The lack of financial and technical capabilities for the use of modern software and applications in publishing, which makes us rely on paper publishing methods.

Note: [a] IHSN: International Household Survey Network.

[b] Anonymization of data refers to the procedures of removing and modifying all individual identifiers (such as the name of the person, address and so forth) from digitized census microdata.

Annex 3. Existing hardware and Software at CSO

Item	Hardware	Qty	Software	Qty
1	PC Desktop	80	Arc GIS Enterprise Advance 10.8	1
2	Laptop	20	Arc GIS desktop standard 10.8	80
3	Plotter A0	2	Arc GIS desktop advance 10.8	20
4	Scanner A0 (not supplied yet)	/	Arc GIS Image Server 10.8	1
5	Scanner A3-A4	2	SQL Server Enterprise (not supplied yet)	/
6	Printer	2	Microsoft Office 2019	100
7	Servers	6	Microsoft Power BI	5
8	Data Storage Device	1	Adobe InDesign	5
9	UPS	1		
10	Rack	1		
11	KVM Rack Amount	1		
12	Core Switch	1		

Geospatial information methodologies and technologies have been adopted by National Statistical Organizations (NSOs), including in many developing countries, in the recognition that the appropriate use and application of these technologies enhances efficiency in the preparatory, enumeration, processing and dissemination phases of the population and housing census and, ultimately, its overall quality. Today, virtually every NSO uses GIS to create digital maps, create and maintain databases, disseminate geostatistical products, and provide a wide range of services. Building a statistical-geospatial infrastructure in support of censuses and statistical activities is particularly recognized as an enabler for facilitating data sharing and improving the availability and access of country information in support of evidence-based decision making and sustainable development.

It is under this mandate that the Central Organization for Statistics and Information Technology (COSIT) in Iraq aims to use innovative geospatial information technologies in support of the upcoming census, and to proceed with their adoption and implementation in accordance with United Nations recommendations, taking into account their specific national circumstances. In this context, ESCWA has commissioned this assessment report which identifies the scope and the gaps of the existing geospatial infrastructure within the Statistical Office in Iraq, with operational guidelines on how to use the geospatial information technologies at every stage of the census, and which identifies the resources and capacities to carry out their implementation and monitoring.

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